SCIENTIFIC DIALOGUES,

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

NATURAL AND EXPERIMENTAL

PHILOSOPHY

ARE FULLY EXPLAINED.

VOL. II. OF ASTRONOMY.

"*Conversation, with the habit of explaining the meaning of words, "and the structure of common domestic implements to children, is the "sure and effectual method of preparing the mind for the acquirement of "science.*" EDGEWORTH'S PRACTICAL EDUCATION.

BY THE REV. J. JOYCE.

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TO

VOL. II.

CONVERSATION I.

OF THE FIXED STARS.

TUTOR — CHARLES — JAMES.

CHARLES. The delay occasioned by our long walk, has afforded us one of the most brilliant views of the heavens that I ever saw.

James. It is uncommonly clear; and the longer I keep my eyes fixed upwards, the more stars seem to appear: how is it possible to number these stars? and yet I have heard

that they are numbered, and even arranged in catalogues according to their apparent magnitudes. Pray, Sir, explain to us how this business was performed.

Tutor. This I will do, with great pleasure, some time hence; but at present I must tell you, that, in viewing the heavens with the naked eye, we are very much deceived as to the supposed number of stars that are at any time visible. It is generally admitted, and on good authority too, that there are never more than one thousand stars visible to the sight, unassisted by glasses, at any one time, and in one place.

James. What! can I see no more than a thousand stars if I look all around the heavens? I should suppose there were millions.

Tutor. This number is certainly the limit of what you can at present behold; and that which leads you, and persons in general, to conjecture that the number is so much larger is owing to an optical deception.

James. Are we frequently liable to be deceived by our senses?

Tutor. We are, if we depend on them *singly*; but where we have an opportunity of calling in the assistance of one sense to the aid of another, we are seldom subject to this inconvenience.

Charles. Do you not know, that if you place a small marble in the palm of the left hand, and then cross the second finger of the right hand over the first, and in that position, with your eyes shut, move the marble with those parts of the

two fingers at once, which are not accustomed to come into contact with any object at the same time, that the one marble will appear to the touch as two? In this instance, without the assistance of our eyes, we should be deceived by the sense of feeling.

Tutor. This is to the point, and shows that the judgment formed by means of a single sense is not always to be depended upon.

James. I recollect the experiment very well, we had it from papa, a great while ago. But that has nothing to do with the false judgment which we are said to form about the number of stars.

Tutor. You are right; it does not immediately concern the subject before us, but it may be useful as

affording a lesson of modesty, by instructing us that we ought not to close our minds against new evidence that may be offered upon any topic, notwithstanding the opinions we may have already formed. You say, you see millions of stars, whereas the ablest astronomers assert, that with the naked eye you cannot at one time see so many as a thousand.

Charles. I should indeed have thought with my brother, had you not asserted the contrary; and I am anxious to know how the deception happens, for I am sure there must be a great deception somewhere, if I do not at this time behold very many thousands of stars in the heavens.

Tutor. You know that we see objects only by means of the rays

of light which proceed from them in every direction. And you must, for the present, give me credit when I tell you, that the distance of the fixed stars from us is immensely great; consequently the rays of light have to travel this distance; in the course of which, especially in their passage through our atmosphere, they are subject to numberless *reflections* and *refractions*. By means of these, other rays of light come to the eye, every one of which, perhaps, impresses upon the mind the idea of so many separate stars. Hence arises that optical fallacy by which we are led to believe the stars that we behold are innumerable.

James. I should like to see an experiment to confirm this.

Tutor. I have no objection: in

every case you ought to require the best evidence that the subject will admit of: —

To ask or search I blame thee not, for heaven
Is as the book of God before thee set,
Wherein to read his wondrous works, and learn
His seasons, hours, or days, or months, or years.

MILTON.

I will show you two experiments which will go a good way to remove the difficulty. But, for this purpose, we must step into the house.

Here are two common looking-glasses, which, philosophically speaking, are *plane mirrors*. I place them in such a manner on the table that they support one another from falling by meeting at the tops. I now place this half-crown between them, on a book, to raise it a little above the table. Tell me how many pieces

of money you would suppose there were, if you did not know that I had used but one.

James. There are several in the glasses.

Tutor. I will alter the position of the glasses a little, by making them almost parallel to one another; now look into them, and say what you see.

James. There are more half-crowns now than there were before.

Tutor. It is evident, then, that by *reflection* only, a single object, for I have made use of but one half-crown, will give you the idea of a vast number.

Charles. If a little contrivance had been used to conceal the method of making the experiment, I should not have believed but that there had

been several half-crowns instead of one.

Tutor. Bring me your multiplying glass; look through it at the candle: how many do you see? or rather, how many candles should you suppose there were, did you not know that there was but one on the table?

James. A great many, and a pretty sight it is.

Charles. Let me see; yes, there are: but I can easily count them; there are sixteen.

Tutor. There will be just as many images of the candle, or any other object at which you look, as there are different surfaces on your glass. For, by the principle of *refraction*, the image of the candle is seen in as many different places as the glass has

surfaces; consequently, if instead of 16 there had been 60, or, if they could have been cut and polished so small, 600, then the single candle would have given you the idea of 60, or 600. What think you now about the stars?

James. Since I have seen that *reflection* and *refraction* will each, singly, afford such optical deceptions, I can no longer doubt, but that, if both these causes are combined, as you say they are with respect to the rays of light coming from the fixed stars, a thousand real luminaries may have the power of exciting in my mind the idea of millions.

Tutor. I will mention another experiment, for which you may be prepared against the next clear star-light night. Get a long narrow tube,

the longer and narrower the better, provided its weight does not render it unmanageable: examine through it any one of the largest fixed stars; which are called stars of the *first* magnitude, and you will find, that though the tube takes in as much sky as would contain many such stars, yet that the single one, at which you are looking, is scarcely visible, by the few rays which come *directly* from it: this is another proof that the brilliancy of the heavens is much more owing to *reflected* and *refracted* light, than to the direct rays flowing from the stars.

CONVERSATION II.

Of the Fixed Stars.

CHARLES. Another beautiful evening presents itself; shall we take the advantage which it offers of going on with our astronomical lectures?

Tutor. I have no objection, for we do not always enjoy such opportunities as the brightness of the present evening affords.

James. I wish very much to know how to distinguish the stars, and to be able to call them by their proper names.

Tutor. This you may very soon learn; a few evenings, well improved, will enable you to distinguish all the stars of the first magnitude which are visible, and all the relative positions of the different constellations.

James. What are constellations, Sir?

Tutor. The ancients, that they might the better distinguish and describe the stars with regard to their situation in the heavens, divided them into constellations, that is, systems of stars, each system consisting of such stars as were near to each other, giving them the names of such men or things, as they fancied the space which they occupied in the heavens represented.

Charles. Is it then perfectly arbi-

trary, that one collection is called the *Great Bear*, another *the Dragon*; a third *Hercules*, and so on?

Tutor. It is; and though there have been additions to the number of stars in each constellation, and various new constellations invented by modern astronomers, yet the original division of the stars into these collections was one of those few arbitrary inventions which has descended without alteration, otherwise than by addition, from the days of Ptolemy down to the present time.—Do you know how to find the four cardinal points, as they are usually called, the North, South, West, and East?

James. O yes, I know that if I look at the sun at twelve o'clock at noon, I am also looking to the south,

where he then is; my back is towards the north; the west is on my right hand, and the east on my left.

Tutor. But you must learn to find these points without the assistance of the sun, if you wish to be a young astronomer.

Charles. I have often heard of the *north pole star*; that will perhaps answer the purpose of the sun, when he has left us.

Tutor. You are right; do you see those seven stars which are in the constellation of the *Great Bear*? Some people have supposed their position will aptly represent a *plough*; others say, that they are more like a *waggon and horses*;—the four stars representing the body of the waggon, and the other three the horses, and hence they are called by some

the plough, and by others they are called Charles's wain or waggon. Here is a drawing of it (Plate I, Fig. 1); *a b d g* represent the four stars, and *e z* B the other three.

Charles. What is the star P?

Tutor. That represents the polar star to which you just now alluded; and you observe, that if a line were drawn through the stars *b* and *a*, and produced far enough, it would nearly touch it.

James. Let me look in the heavens for it by this guide. There it is, I suppose; it shines with a steady and rather dead kind of light, and it appears to me that it would be a little to the right of the line passing through the stars *b* and *a*.

Tutor. It would; and these stars are generally known by the name of

the *pointers*, because they point to *p* the north pole, which is situated a little more than two degrees from the star P.

Charles. Is that star always in the same part of the heavens?

Tutor. It may be considered as uniformly maintaining its position, while the other stars seem to move round it as a centre. We shall have occasion to refer to this star again; at present I have directed your attention to it, as a proper method of finding the cardinal points by starlight.

James. Yes, I understand now, that if I look to the north, by standing with my face to that star, the south is at my back, on my right hand is the east, and the west on my left.

Tutor. This is one important step in our astronomical studies; and we can make use of these stars as a kind of standard, in order to discover the names and positions of others in the heavens.

Charles. In what way must we proceed in this business?

Tutor. I will give you an example or two: conceive a line drawn from the star *z*, leaving B a little to the left, and it will pass through that very brilliant star A near the horizon towards the west.

James. I see the star, but how am I to know its name?

Tutor. Look on the celestial globe for the star *z*, and suppose the line drawn on the globe, as we conceived it done in the heavens, and you will find the star, and its name.

Charles. Here it is;—its name is Arcturus.

Tutor. Take the figure (Fig. 1), and place Arcturus at A, which is its relative position, in respect to the constellation of the Great Bear. Now, if you conceive a line drawn through the stars *g* and *b*, and extended a good way to the right, it will pass just above another very brilliant star. Examine the globe as before, and find its name.

Charles. It is *Capella*, the *goat*.

Tutor. Now, whenever you see any of these stars, you will know where to look for the others without hesitation.

James. But do they never move from their places?

Tutor. With respect to us, they seem to move together with the whole

heavens. But they always remain in the same relative position, with respect to each other. Hence they are called *fixed* stars, in opposition to the *planets*, which, like our earth, are continually changing their places, both with regard to the fixed stars and to themselves also.

Charles. I now understand pretty well the method of acquiring a knowledge of the names and places of the stars.

Tutor. And with this we will put an end to our present Conversation.

CONVERSATION III.

Of the Fixed Stars, and Ecliptic.

TUTOR. I dare say, that you will have no difficulty in finding the north polar star, as soon as we go into the open air.

James. I shall at once know where to look for that and the other stars, which you pointed out last night, if they have not changed their places.

Tutor. They always keep the same position with respect to each other, though their situation, with regard to the heavens, will be dif-

ferent at different sessons of the year and in different hours of the night. Let us go into the garden.

Charles. The stars are all in the same place as we left them last evening. Now, Sir, if we conceive a straight line drawn through the two stars in the plough, which, in your figure (Fig. 1), are marked *d* and *g*, and to extend a good way down, it will pass or nearly pass through a very bright star, though not so bright as *Arcturus* or *Capella*, what is that called?

Tutor. It is a star of the second magnitude, and if you refer to the celestial globe, in the same way as you were instructed last night, you will find it is called *Regulus* or *Cor Leonis*, the *Lion's heart*. By this method you may quickly discover the

names of all the principal stars, and afterwards, with a little patience, you will easily distinguish the others, which are less conspicuous.

Charles. But they have not all names; how are they specified?

Tutor. If you look on the globe, you will observe that they are distinguished by the different letters of the Greek alphabet; and in those constellations, in which there are stars of different apparent magnitudes, the largest is α alpha, the next in size β beta, the third γ gamma, the fourth δ delta, and so on.

James. Is there any particular reason for this?

Tutor. The adoption of the characters of the Greek alphabet, rather than any other, was perfectly arbitrary: it is, however, of great im-

portance, that the same characters should be used in general by astronomers of all countries, for by this means the science is in possession of a sort of universal language.

Charles. Will you explain how this is?

Tutor. Suppose an astronomer in North America, Asia, or any other part of the earth, observe a comet in that part of the heavens where the constellation of the *plough* is situated, and he wishes to describe it to his friend in Great Britain, in order that he may know, whether it was seen by the inhabitants of this island. For this purpose he has only to mention the time when he discovered it; its position, as nearest to some one of the stars, calling it by the Greek letter by which it is

designated; and the course which it took from one star towards another. Thus he might say, that on such a time he saw a comet near δ in the Great Bear, and that its course was directed from δ to β, or any other, as it happens.

Charles. Then, if his friend here had seen a comet at the same time, he would, by this means, know whether it was the same or a different comet.

Tutor. Certainly; and hence you perceive of what importance it is, that astronomers in different countries should agree to mark the same stars and systems of stars by the same characters. But to return to that star, to which you just called my attention, the *Cor Leonis*, it is not only a remarkable star, but its

position is also remarkable; it is situated in the *ecliptic.*

James. What is that, Sir?

Tutor The *ecliptic* is an imaginary great circle in the heavens, which the sun *appears* to describe in the course of a year. If you look on the celestial globe, you will see it marked with a *red* line, perhaps an emblem of the fierce heat communicated to us by that body.

James. But the sun seems to have a circular motion in the heavens every day?

Tutor. It does; and this is called its apparent *diurnal,* or daily motion, which is very different from the path it appears to traverse in the course of a year. The *former* is observed by the most inattentive spectator, who cannot but know, that the sun is

seen every morning in the east, at noon in the south, and in the evening in the west; but the knowledge of the *latter* must be the result of patient observation.

Charles. And what is the *green* line which crosses it.

Tutor. It is called the *equator;* this is an imaginary circle belonging to the earth, which you must take for granted, a little longer, is of a globular form. If you can conceive the plane of the terrestrial equator to be produced to the sphere of the fixed stars, it would mark out a circle in the heavens, called the *celestial equator* or *equinoctial,* which would cut the *ecliptic* in two parts.

James. Can we trace the circle of the *ecliptic* in the heavens?

Tutor. It may be done with to-

lerable accuracy by two methods; *first*, by observing several remarkable fixed stars, to which the moon in its course seems to approach. The *second* method is by observing the places of the planets.

Charles. Is the moon then always in the ecliptic?

Tutor. Not exactly so; but it is always either in the ecliptic, or within five degrees and a third of it on one side or the other. The planets also, by which I mean, Mercury, Venus, Mars, Jupiter, Saturn, and the Herschel, are never more than eight degrees distant from the line of the ecliptic.

James. How can we trace this line, by help of the fixed stars?

Tutor. By comparing the stars in the heavens with their representa-

tives on the artificial globe, a practice which may be easily acquired, as you have seen. I will mention to you the names of those stars, and you may first find them on the globe, and then refer to as many of them as are now visible in the heavens. The first is in the *Ram's* horn, called *α Arietis*, about ten degrees to the *north* of the ecliptic; the second is the star *Aldebaran* in the *Bull's* eye, six degrees *south* of the ecliptic.

Charles. Then if at any time I see these two stars, I know that the ecliptic runs between them, and nearer to Aldebaran than to that in the Ram's horn.

Tutor. Yes: now carry your eye eastward to a distance somewhat greater from Aldebaran, than that is east of *α* Arietis, and you will per-

ceive two bright stars at a small distance from one another, called *Castor* and *Pollux*; the lower one, and that which is least brilliant, is Pollux, seven degrees on the north side of the ecliptic. Following the same track, you will come to *Regulus*, or the *Cor Leonis*, which, I have already observed, is exactly in the line of the ecliptic. Beyond this, and only two degrees south of that line, you will find the beautiful star in the virgin's hand, called *Spica Virginis*. You then arrive at *Antares*, or the *Scorpion's heart*, five degrees on the same side of the ecliptic. Afterwards you will find *α Aquilæ*, which is situated nearly thirty degrees north of the ecliptic: and farther on is the star *Fomalhaut* in the fish's mouth, about as many degrees south of that line.

The ninth and last of these stars is *Pegasus*, in the wing of the flying-horse, which is north of the ecliptic nearly twenty degrees.

James. Upon what account are these nine stars particularly noticed?

Tutor. They are selected as the most conspicuous stars near the moon's orbit, and are considered as proper stations, from which the moon's distance is calculated for every three hours of time; and hence are constructed those tables in the *Nautical Almanac*, by means of which navigators, in their most distant voyages, are enabled to estimate, on the trackless ocean, the particular part of the globe on which they are.

Charles. What do you mean by the Nautical Almanac?

Tutor. It is a kind of National Almanac, intended chiefly for the use of persons traversing the mighty ocean. It was begun in the year 1767, by Dr. Maskelyne, the Astronomer Royal; and is published by anticipation for several years beforehand, for the convenience of ships going out upon long voyages. This work has been found eminently important in the course of the late voyages round the world for making discoveries.

CONVERSATION IV.

Of the Ephemeris.

CHARLES. Your second method of tracing the ecliptic was by means of the position of the planets; will you explain that now?

Tutor. I will; and, to render you perfectly qualified for observing the stars, I will devote the present Conversation to the purpose of explaining the use of White's Ephemeris, a little book which is published annually, and which is a necessary companion to every young astronomer.

James. Must we understand all this to study the stars?

Tutor. You must, or some other book of the same kind, if you would proceed on the best and most rational plan. Besides, when you know the use of this book, which you will completely with half an hour's attention, you have nothing more to do in order to find the position of the planets at any day of the year, than to turn to that day in the Ephemeris, and you will instantly be directed to those parts of the heavens in which the different planets are situated. Turn to the second page.

Charles. Here the astronomical characters are explained.

Tutor. The first twelve are the representatives of the signs into which

the circle of the ecliptic is divided, called also the twelve signs of the *Zodiac.*

♈ Aries.	♌ Leo.	♐ Sagittarius.
♉ Taurus.	♍ Virgo.	♑ Capricorn.
♊ Gemini.	♎ Libra.	♒ Aquarius.
♋ Cancer.	♏ Scorpio.	♓ Pisces.

Every circle connected with this subject is supposed to be divided into 360 parts, called degrees, and since that of the ecliptic is also divided into 12 signs, each sign must contain 30 degrees. Astronomers subdivide each degree into minutes and seconds; thus, if I would express an angle of 25 degrees, 11 minutes, and 45 seconds, I should write $25^{\circ} . 11' . 45''$. Or, if I would express the situation of the sun for the first of January, 1800, I look into the

Ephemeris and find it in Capricorn, or ♑ 10°. . 56′. . 38″.

James. What do you mean by the Zodiac?

Tutor. It is an imaginary broad circle or belt surrounding the heavens, about sixteen degrees wide; along the middle of which runs the ecliptic. The term Zodiac is derived from a Greek word signifying an animal, because each of the twelve signs formerly represented some animal; that which we now call Libra, being by the ancients reckoned a part of Scorpio.

James. Why are the signs of the Zodiac called by the several names of Aries, Taurus, Leo, &c. I see no likeness in the heavens to Rams, or Bulls, or Lions, which are the English words for those Latin ones?

Tutor. Nor do I; nevertheless, the ancients saw, by the help of a strong imagination, a similarity between those animals and the places which certain systems of stars took up in the heavens, and gave them the names which have continued to this day.

Charles. Perhaps these were originally invented in the same way as we sometimes figure to our imagination the appearances of men, beasts, ships, trees, &c., in the flying clouds or in the fire.

Tutor. They might possibly have no better authority for their origin. At any rate it will be useful for you to have the names of the twelve signs in your memory, as well as the order in which they stand: I will therefore repeat some lines written

by Dr. Watts, in which they are expressed in English, and will be easily remembered:

The *Ram*, the *Bull*, the *heavenly Twins*,
And next the *Crab* the *Lion* shines,
The *Virgin* and the *Scales*;
The *Scorpion*, *Archer*, and Sea-*Goat*,
The *Man* that holds the *watering-pot*,
And *Fish* with glittering tails.

Charles. We come now to the characters placed before the planets.

Tutor. These, like the former, are but a kind of short-hand characters, which it is esteemed easier to write than the names of the planets at length. They are as follow:—

♅ The Herschel.	☉ The Sun.
♄ Saturn.	♀ Venus.
♃ Jupiter.	☿ Mercury.
♂ Mars.	☽ The Moon.
⊖ The Earth.	

With the other characters you have no need to trouble yourselves, till you come to calculate eclipses, and construct astronomical tables, a labour which may be deferred for some years to come. Turn to the eighth page of the Ephemeris.

James. Have we no concern with the intermediate pages between the second and eighth?

Tutor. They do not contain any thing that requires explanation. In the eighth page, after the common almanac for January, the first two columns point out the exact time of the sun's rising and setting at London: thus on the 10th day of January he rises at 58 minutes after 7 in the morning, and sets at two minutes past 4 in the afternoon. The

third column gives the *declination* of the sun.

James. What is that, Sir?

Tutor. The *declination* of the sun, or of any heavenly body, is its distance from the imaginary circle in the heavens, called the *equinoctial.* Thus you observe that the sun's declination on the 1st of January is 23°..4′ south; or, it is so many degrees south of the imaginary *equator.* Turn to March 1803, and you will see that between the 20th and 21st days it is in the equator, for at 12 o'clock at noon on the 20th it is only 25′ south, and at the same hour on the 21st it is 1′ north of that line: and when it is in the equator, then it has no declination.

Charles. Do astronomers always reckon from 12 o'clock at noon?

Tutor. They do: and hence the astronomical day begins 12 hours *later* than the day according to common reckoning; and therefore the declination, longitude, latitude, &c., of the sun, moon, and planets, are always put down for 12 o'clock at noon of the day to which they are opposite. Thus the sun's declination for the 16th of January at 12 o'clock is 20°..56′ south.

Charles. Is that because it is the commencement of the astronomical day, though in common life it be called 12 o' clock?

Tutor. It is. The three next columns contain the moon's declination, the time of her rising and setting, and the time of her *southing*, or when she comes to the meridian or south part of the heavens.

Charles. Does she not come to the south at noon as well as the sun?

Tutor. No; the moon never comes to the meridian at the same time as the sun, but at the time of *new* moon. And this circumstance takes place at every new moon, as you may see by casting your eye down the several columns in the Ephemeris which relate to the moon's southing.

The glory, the changes, and the motion of the moon, are beautifully described in the following lines:—

By thy command the Moon, as day-light fades,
Lifts her broad circle in the deep'ning shades;
Array'd in glory, and enthron'd in light,
She breaks the solemn terrors of the night;
Sweetly inconstant in her varying flame,
She changes still, another, yet the same!
Now in decrease, by slow degrees she shrouds
Her fading lustre in a veil of clouds;

Now of increase her gath'ring beams display
A blaze of light, and give a paler day.
Ten thousand stars adorn her glitt'ring train,
Fall when she falls, and rise with her again;
And o'er the deserts of the sky unfold
Their burning spangles of sidereal gold:
Through the wide heav'ns she moves serenely
    bright,
Queen of the gay attendants of the night;
Orb above orb in sweet confusion lies,
And with a bright disorder paints the skies.

BROOME.

James. What do you say of the 7th column;—*the clock before the sun?*

Tutor. A full explanation of that must be deferred, till we come to speak of the *equation of time;* at present it will be sufficient for you to know, that if you are in possession of a very accurate and well regulated clock, and also of an excellent sun-dial, they will be together only

four days in a year; now this 7th column in the Ephemeris points out how much the clock is before the sun, or the sun before the clock, for every day in the year. On *twelfth-day*, 1809, for instance, the clock is faster than the sun by 6 minutes and 12 seconds: but if you turn to *May-day*, you will find that the clock is 3′..4″ slower than the sun.

James. What are the four days in the year when the clock and dial are together?

Tutor. About the 15th of April, the 15th of June, the 1st of September, and Christmas-day.

Charles. By this table then we may regulate our clocks and watches.

James. In what manner?

Charles. Examine on any particular day the clock or watch, and dial

at the same time, say 12 o'clock, and observe whether the difference between them answer to the difference set down in the table, opposite to the day of observation. Thus on the 12th of March 1809, the clock will not show true time unless it be 10′..3″ before the dial, or when the dial is 12 o'clock it must be 10′..3″ past 12 by the clock or watch.

Tutor. Well, let us proceed to the next page. The first three *short* columns, relating only to the duration of daylight and twilight, require no explanation: the fourth we shall pass over for the present; and the remaining five give the *latitude* of the planets.

James. What do you mean by the latitude, Sir?

Tutor. The latitude of any heavenly body is its distance from the

ecliptic north or south. The latitude of *Venus*, on new-year's day, 1803, is 4° north.

Charles. Then the *latitude* of heavenly bodies has the same reference to the *ecliptic*, that *declination* has to the equator?

Tutor. It has.

James. But I do not see any table of the sun's latitude.

Tutor. I dare say your brother can give you a reason for this.

Charles. Since the latitude of a heavenly body is its *distance from* the ecliptic, and since the sun is always in the ecliptic, therefore he can have no latitude.

Tutor. The *longitude* of the sun and planets is the only thing in this page that remains to be explained. The longitude of a heavenly body is

its distance from the first point of the sign Aries, and it is measured on the ecliptic. It is usual, however, as you observe in the Ephemeris, to express the longitude of a heavenly body by the degree of the sign in which it is. In this way the sun's longitude on the first of January, 1809, is in Capricorn 10°.. 45′.. 14″; that of the moon in Cancer 6°.. 4′; that of Jupiter is in Pisces 13°.. 35′.

Charles. There are some short columns at the bottom of the former page that you have omitted.

Tutor. The use of these will be better understood when we come to converse respecting the planets*.

* For the explanation of Heliocentric Longitude, see Conversation XX.

CONVERSATION V.

Of the Solar System.

TUTOR. We will now proceed to the description of the *Solar System.*

James. Of what does that consist, Sir?

Tutor. It consists of the sun, and planets, with their satellites, or moons. It is called the *Solar System,* from *Sol,* the sun, because the sun is supposed to be fixed in the centre, while the planets, and our earth among them, revolve round him at different distances.

Charles. But are there not some people who believe that the sun goes round the earth?

Tutor. Yes, it is an opinion embraced by the generality of persons, not accustomed to reason on these subjects. It was adopted by Ptolemy, who supposed the earth perfectly at rest, and the sun, planets, and fixed stars to revolve about it every twenty-four hours.

James. And is not that the most natural supposition?

Tutor. If the sun and stars were small bodies in comparison of the earth, and were situated at no very great distance from it, then the system maintained by Ptolemy and his followers might appear the most probable.

James. Are the sun and stars very large bodies then?

Tutor. The sun is more than a million of times larger than the earth which we inhabit, and many of the fixed stars are probably much larger than he is.

Charles. What is the reason, then, that they appear so small?

Tutor. This appearance is caused by the immense distance there is between us and these bodies. It is known with certainty, that the sun is more than 95 millions of miles distant from the earth, and the nearest fixed star is probably more than two hundred thousand times farther from us than even the sun himself*.

* The young reader will, when he is able to manage the subject, see this clearly de-

Charles. But we can form no conception of such distances.

Tutor. We talk of millions with as much ease as of hundreds or tens, but it is not, perhaps, possible for the mind to form any adequate conceptions of such high numbers. Several methods have been adopted to assist the mind in comprehending the vastness of these distances. You have some idea of the swiftness with which a cannon-ball proceeds from the mouth of the gun?

James. I have heard at the rate of eight miles in a minute.

Tutor. And you know how many minutes there are in a year?

monstrated by a series of propositions in the fifth book of Dr. Enfield's Institutes of Natural Philosophy, second edition.—See p. 346 to the end of Book V.

James. I can easily find that out by multiplying 365 days by 24 for the number of hours, and that product by 60, and I shall have the number of minutes in a year, which number is 525,600.

Tutor. Now if you divide the distance of the sun from the earth by the number of minutes in a year multiplied by 8, because the cannon-ball travels at the rate of 8 miles in one minute, you will know how long any body issuing from the sun, with the velocity of a cannon-ball, would employ in reaching the earth.

Charles. If I divide 95,000,000 by 525,600, multiplied by 8, or 4,204,800, the answer will be more than 22, the number of years taken for the journey.

Tutor. Is it then probable that bodies so large, and at such distances from the earth, should revolve round it every day?

Charles. I do not think it is.— Will you, Sir, go on with the description of the *Solar System?*

Tutor. According to this system, the sun is in the centre, about which the planets revolve from *west to east*, according to the order of the signs in the ecliptic; that is, if a planet is seen in Aries, it advances to Taurus, then to Gemini, and so on.

James. How many planets are there belonging to the sun?

Tutor. There are seven, besides some smaller bodies of the same kind discovered within these nine years. c (Plate I, Fig. 2) represents the sun, the nearest to which, *Mercury*, revolves

in the circle *a*; next to him is the beautiful planet *Venus*, who performs her revolution in the circle *b*; then comes the *Earth* in *t*; next to which is *Mars* in *e*; then *Jupiter* in the circle *f*; afterwards *Saturn* in *g*; and far beyond him the *Herschel* planet performs his revolution in the circle *h*. Do you recollect the lines in Thomson's Summer?

——————— and thou, O Sun,
Soul of surrounding worlds! in whom best seen
Shines out thy MAKER! may I sing of thee?
'Tis by thy secret strong attractive force,
As with a chain indissoluble bound,
Thy system rolls entire: from the far bourne
Of utmost *Herschel*, wheeling wide his round
Of *fourscore* years, to Mercury, whose disk
Can scarce be caught by philosophic eye,
Lost in the near effulgence of thy blaze.

Charles. You have substituted the words Herschel, and fourscore,

for Saturn, and thirty. These lines are descriptive of the figure.

James. For what are the smaller circles, which are attached to several of the larger ones, intended?

Tutor. They are intended to represent the *orbits* of the several satellites or moons belonging to some of the planets.

James. What do you mean by the word orbit?

Tutor. The path described by a planet in its course round the sun, or by a moon round its primary planet, is called its *orbit.* Look to the orbit of the earth in *t* (Fig. 2) and you will see a little circle, which represents the orbit in which our moon performs its monthly journey.

Charles. Has neither *Mercury* nor *Venus* any moon?

Tutor. None have ever been discovered belonging either to Mercury, Venus, or Mars. Jupiter, as you observe by the figure, has four moons: Saturn has seven: and the Herschel (which also goes by the name of the Georgium Sidus) has six; these for want of room are not drawn in the plate.

Charles. The *Solar System* then consists of the sun as a centre, round which revolve *seven* planets, and *eighteen* satellites or moons. Are there no other bodies belonging to it?

Tutor. Yes, as I just observed, four other planetary bodies have been very lately discovered as belonging to the Solar System. These are very small, and named from the gentlemen who discovered them, who were Messrs. Piazzi, Olbers, and Harding. They are also called the *Ceres Fer-*

dinandea, *Pallas*, *Juno*, and *Vesta*. There are comets also which make their appearance occasionally; and it would be wrong positively to affirm, that there can be no other planets belonging to the Solar System; since, besides the four bodies just mentioned, it is only within these thirty years that the seventh or the Herschel has been known to exist as a planet connected with this system.

Charles. Who first adopted the system of the world which you have been describing?

Tutor. It was conceived and taught by Pythagoras to his disciples, 500 years before the time of Christ. But it seems soon to have been disregarded, or perhaps totally rejected, till about 300 years ago, when it was revived by Copernicus, and is at

length generally adopted by men of science:—

The sun revolving on his axis turns,
And with creative fire intensely burns;
Impell'd the forcive air, our earth supreme
Rolls with the planets round the solar gleam:
First Mercury completes his transient year,
Glowing refulgent, with reflected glare;
Bright Venus occupies a wider way;
The early harbinger of night and day;
More distant still our globe terraqueous turns,
Nor chills intense, nor fiercely heated burns.
Around her rolls the lunar orb of light,
Trailing her silver glories through the night;
Beyond our globe the sanguine Mars displays
A strong reflection of primeval rays;
Next belted Jupiter far distant gleams,
Scarcely enlighten'd with the solar beams;
With four unfix'd receptacles of light
He tow'rs majestic through the spacious height;
But farther yet the tardy Saturn lags,
And seven attendant luminaries drags;
Investing with a double ring his pace,
He circles through immensity of space.

CHATTERTON.

CONVERSATION VI.

Of the Figure of the Earth.

TUTOR. Having, in our last Conversation, given you a description of the Solar System in general, we will now proceed to consider each of its parts separately; and since we are most of all concerned with the *earth*, we will begin with that body.

James. You promised to give us some reasons why this earth must be in the form of a globe, and not a mere extended plane, as it appears to common observation.

Tutor. Suppose you were standing by the sea-shore, on a level with

the water, and at a very considerable distance, as far as the eye can reach, you observe a ship approaching, what ought to be the appearance, supposing the surface of the sea be a flat plane?

Charles. We should, I think, see the whole ship at once, that is, the hull would be visible as soon as the top-mast.

Tutor. It certainly must, or indeed rather sooner, because the body of the vessel being so much larger than a slender mast, it must necessarily be visible at a greater distance.

James. Yes, I can see the steeple of a church at a much greater distance than I can discern the iron conductor which is upon it, and that I can perfectly see long before the little piece of gold wire, which is fixed at its extremity, is visible.

Tutor. Well, but the top-mast of a vessel at sea is always in view some little time before the hull of the vessel can be discerned. Now, if the surface of the sea be globular, this ought to be the appearance, because the protuberance or swelling of the water between the vessel and the eye of the spectator, will hide the body of the ship some time after the pendant is seen above.

Charles. In the same way as if a high building, a church for instance, were situated on one side of a hill, and I was walking up on the opposite side, the steeple would come first in sight, and as I advanced towards the summit, the other parts would come successively in view.

Tutor. Your illustration is quite to the purpose: in the same way two

persons, walking up a hill on the opposite sides, will perceive each other's heads first; and as they advance to the top, the other parts of their bodies will become visible. With respect to the ship, the following figure will convey the idea very completely. (Plate I, Fig. 3.) Suppose C A B represent a small part of the curved surface of the sea; if a spectator stand at B, while a ship is at C, only a small part of the mast is visible to him, but as it advances, more of the ship is seen, till it arrive at *e*, when the whole will be in sight: —

Behold, when the glad ship shoots from the
    port
Upon full sail, the hulk first disappears,
And then the lower, then the higher sails;
At length the summit of the tow'ring mast
Alone is seen: nor less, when from the ship
The longing sailor's eye in hope of shore:

For then, from the top-mast, tho' more remote
Than either deck, the shore is first beheld.

LOFFT'S EUDOSIA.

Charles. When I stood by the sea-side the water did *not* appear to me to be curved.

Tutor. Perhaps not: but its convexity may be discovered upon any still water; as upon a river, which is extended a mile or two in length, for you might see a very small boat at that distance while standing upright; if then you stoop down so as to bring your eye near the water, you will find the surface of it rising in such a manner as to cover the boat, and intercept its view completely. Another proof of the globular figure of the earth is, that it is necessary for those who are employed in cutting canals, to make a

certain allowance for the convexity; since the true level is not a straight line, but a curve which falls below it eight inches in every mile.

Charles. I have heard of people sailing round the world, which is another proof, I imagine, of the globular figure of the earth.

Tutor. It is a well known fact, that navigators have set out from a particular port, and by steering their course continually westward, have at length arrived at the same place from whence they first departed. Now had the earth been an extended plane, the longer they had travelled, the farther must they have been from home.

Charles. How is it known that they continued the same course? Might they not have been driven round at open sea?

Tutor. By means of the mariner's compass, the history, properties, and uses of which, I will explain very particularly in a future part of our lectures, the method of sailing on the ocean by one certain tract is as sure as travelling on the high London road from the metropolis to York. By this method, Ferdinand Magellan sailed, in the year 1519, from the western coast of Spain, and continued his voyage in a westward course till he arrived after 1124 days in the same port from whence he set out. The same, with respect to Great Britain, was done by our own countrymen sir Francis Drake, lord Anson, captain Cook, and many others.

Charles. Is then the common terrestrial globe a just representation of the earth?

Tutor. It is, with this small difference*, that the artificial globe is a perfect sphere, whereas the earth is a spheroid, that is, in the shape of an orange, the diameter from *pole* to *pole* being about 37 miles shorter than that at the *equator*.

James. What are the poles, Sir?

* What the earth loses of its sphericity, by mountains and vallies, is very inconsiderable: the highest mountain bearing so little proportion to its bulk, as scarcely to be equivalent to the minutest protuberance on the surface of an orange:—

These inequalities to us seem great;
But to an eye that comprehends the whole,
The tumour, which to us so monstrous seems,
Is as a grain of sparkling sand that clings
To the smooth surface of a sphere of glass;
Or as a fly upon the convex dome
Of a sublime, stupendous edifice.

LOFFT.

Tutor. In the artificial globe (Plate I, Fig. 4) there is an axis N S about which it turns; now the two extremities or ends of this axis N and S are called the poles.

The globe terrestrial, with its slanting poles,
And all its pond'rous load, unwearied rolls.

BLACKMORE.

Charles. Is there any axis belonging to the earth?

Tutor. No; but, as we shall to-morrow show, the earth turns round once in every 24 hours, so astronomers imagine an axis upon which it revolves as upon a centre, the extremities of which imaginary axis are the poles of the earth: of these N the north pole points at all times exactly to *p* (Fig. 1), the north pole of the heavens which we have already described, and which is, as

you recollect, within two degrees of the polar star.

James. And how do you define the *equator?*

Tutor. The *equator* A B (Fig. 4) is the circumference of an imaginary circle passing through the centre of the earth, perpendicular to the axis N S, and at equal distances from the poles.

Charles. And I think you told us, that if we conceived this circle extended every way to the fixed stars it would form the *celestial equator.*

Tutor. I did; it is also called the *equinoctial*, and you must not forget, that in this case it would cut the circle of the ecliptic C D in two points.

James. Why is the *ecliptic* marked on the terrestrial globe, since it is a circle peculiar to the heavens?

Tutor. Though the *ecliptic* be peculiar to the heavens, and the *equator* to the earth, yet they are both drawn on the terrestrial and celestial globes, in order, among other things, to show the position which these imaginary circles have to one another.

I shall now conclude our present Conversation, with observing, that, besides the proofs adduced for the globular form of the earth, there are others equally conclusive, which will be better understood a few days hence.

CONVERSATION VII.

Of the Diurnal Motion of the Earth.

TUTOR. Well, gentlemen, are you satisfied that the earth on which you tread is a globular body, and not a mere extended plane?

Charles. Admitting the facts which you mentioned yesterday, *viz.* that the top-mast of a ship at sea is always visible before the body of the vessel comes into sight;—that navigators have repeatedly, by keeping the same direction, sailed round the world;—and that persons employed in digging canals, can only execute their work

with effect, by allowing for the supposed globular shape of the earth, it is evident the earth cannot be a mere extended plane.

James. But all these facts can be accounted for, upon the supposition that the earth is a globe, and therefore you conclude it is a globe: this was, I believe, the nature of the proof?

Tutor. It was; let us now advance one step farther, and show you that this globe turns on an imaginary axis every twenty-four hours; and thereby causes the succession of day and night:—

And earth self-balanc'd on her centre hung.
PAR. LOST.

James. I shall wonder if you are able to afford such satisfactory evi-

dence of the daily motion of the earth, as of its globular form.

Tutor. I trust, nevertheless, that the arguments on this subject will be sufficiently convincing, and that before we part you will admit, that the apparent motion of the sun and stars is occasioned by the diurnal motion of the earth.

Charles. I shall be glad to hear how this can be proved; for if, in the morning, I look at the sun when rising, it appears in the east, at noon it has travelled to the south, and in the evening I see it set in the western part of the heavens.

James. Yes, and we observed the same last night (March the 1st) with respect to *Arcturus*, for about eight o'clock it had just risen in the north-west part of the heavens, and

when we went to bed two hours after, it had ascended a good height in the heavens, evidently travelling towards the west.

Tutor. It cannot be denied that the heavenly bodies appear to rise in the east and set in the west; but the *appearance* will be the *same* to us, whether those bodies revolve about the earth while that stands still, or they stand still while the earth turns on its axis the contrary way.

Charles. Will you explain this, Sir?

Tutor. Suppose G R C B (Plate II, Fig. 5) to represent the earth, T the centre on which it turns from west to east, according to the order of the letters G R C B. If a spectator on the surface of the earth at R see a star at H, it will appear to him to

have just risen; if now the earth be supposed to turn on its axis a fourth part of a revolution, the spectator will be carried from R to C, and the star will be just over his head; when another fourth part of the revolution is completed, the spectator will be at B, and to him the star at H will be setting, and will not be visible again till he arrive, by the rotation of the earth, at the station R.

Charles. To the spectator, then, at R, the appearance would be the same whether he turned with the earth into the situation B, or the star at H had described, in a contrary direction, the space H Z O in the same time.

Tutor. It certainly would.

James. But if the earth really turned on its axis, should we not perceive the motion?

Tutor. The earth, in its diurnal rotation, being subject to no impediments by resisting obstacles, its motion cannot affect the senses. In the same way ships on a smooth sea are frequently turned entirely round by the tide, without the knowledge of those persons who happen to be busy in the cabin between the decks.

Charles. That is, because they pay no attention to any other object but the vessel in which they are. Every part of the ship moves with themselves.

James. But if, while the ship is turning without their knowledge, they happen to be looking at fixed distant objects, what will be the appearance?

Tutor. To them, the objects which are at rest will appear to be

turning round the contrary way. In the same manner we are deceived in the motion of the earth round its axis; for if we attend to nothing but what is connected with the earth, we cannot perceive a motion of which we partake ourselves; and if we fix our eyes on the heavenly bodies, the motion of the earth being so easy, they will appear to be turning in a direction contrary to the real motion of the earth.

Charles. I have sometimes seen a skylark hovering and singing over a particular field for several minutes together; now, if the earth is continually in motion while the bird remains in the same part of the air, why do we not see the field, over which he first ascended, pass from under him?

Tutor. Because the atmosphere, in which the lark is suspended, is connected with the earth, partakes of its motion, and carries the lark along with it; and therefore, independently of the motion given to the bird by the exertion of its wings, it has another in common with the earth, yourself, and all things on it, and, being common to us all, we have no methods of ascertaining the fact by means of the senses. The rotation of the earth on its axis, the smoothness of its motion, and its effect on the atmosphere, are described by Milton in three lines:—

———— That spinning sleeps
On her soft axle as she paces even,
And bears us swift with the smooth air along.

James. Though the motion of a ship cannot be observed without ob-

jects at rest to compare with it, yet I cannot help thinking, that, if the earth moved we should be able to discover it by means of the stars, if they are fixed.

Tutor. Do you not remember once sailing very swiftly on the river, when you told me that you thought all the trees, houses, &c., on its banks were in motion?

James. I now recollect it well, and I had some difficulty in persuading myself that it was not so.

Charles. This brings to my mind a still stronger deception of this sort: when travelling with great speed in a post-chaise, I suddenly waked from a sleep in a smooth but narrow road, and I could scarcely help thinking, for several minutes, but that the trees and hedges were running

away from us, and not we from them.

Tutor. I will mention another curious instance of this kind; if you ever happen to travel pretty swiftly in a carriage by the side of a field ploughed into long narrow ridges, and perpendicular to the road, you will think that all the ridges are turning round in a direction contrary to that of the carriage. These facts may satisfy you that the appearances will be precisely the same to us, whether the earth turn on its axis from west to east, or the sun and stars move from east to west.

James. They will: but which is the more natural conclusion?

Tutor. This you shall determine for yourself. If the earth (Fig. 4) turns on its axis in 24 hours, at what

rate will any part of the equator A B move?

Charles. To determine this we must find the measure of its circumference, and then dividing this by 24, we shall get the number of miles passed through in an hour.

Tutor. Just so: now call the semidiameter of the earth 4000 miles, which is rather more than the true measure.

James. Multiplying this by six* will give 24,000 miles for the cir-

* If the reader would be accurate in his calculations, he must take the mean radius of the earth at 3965 miles, and this multiplied by 6,28318, will give 24,912 miles for the circumference. Through the remainder of this work, the decimals in multiplication are omitted, in order that the mind may not be burdened with odd numbers. It seemed necessary, however, in this place, to give the true semi-diameter of

cumference of the earth at the equator, and this, divided by 24, gives 1000 miles for the space passed through in an hour.

Tutor. You are right. The sun, I have already told you, is 95 millions of miles distant from the earth; tell me, therefore, Charles, at what rate that body must travel to go round the earth in 24 hours?

Charles. I will: 95 millions multiplied by six will give 570 millions of miles for the length of his circuit, this divided by 24 gives nearly 24 millions of miles for the space he must

the earth, and the number (accurate to five places of decimals) by which if the radius of any circle be multiplied, the circumference is obtained. Mr. Playfair makes the longest diameter of the earth to be $3962\frac{1}{7}$ miles, and the shorter $3949\frac{1}{2}$ miles.

travel in an hour, to go round the earth in a day.

Tutor. Which now is the more probable conclusion, either that the earth should have a diurnal motion on its axis of 1000 miles in an hour, or that the sun, which is a million of times larger than the earth, should travel 24 millions of miles in the same time?

James. It is certainly more rational to conclude that the earth turns on its axis, the effect of which you told us was the alternate succession of day and night.

Tutor. I did; and on this and some other topics we will enlarge to-morrow.

CONVERSATION VIII.

Of Day and Night.

JAMES. You are now, Sir, to apply the rotation of the earth about its axis to the succession of day and night.

Tutor. I will; and for this purpose, suppose G R C B (Plate II, Fig. 5) to be the earth, revolving on its axis, according to the order of the letters, that is, from G to R, R to C, &c. If the sun be fixed in the heavens at Z, and a line H O be drawn through the centre of the earth T, it will represent that circle, which, when extended to the

heavens, is called the *rational horizon.*

Charles. In what does this differ from the *sensible horizon?*

Tutor. The *sensible horizon* is that circle in the heavens which bounds the spectator's view, and which is greater or less, according as he stands higher or lower. For example; an eye placed at *five* feet above the surface of the earth or sea, sees $2\frac{3}{4}$ miles every way: but if it be at 20 feet high, that is 4 times the height, it will see $5\frac{1}{2}$ miles, or twice the distance*.

Charles. Then the *sensible* differs from the *rational* horizon in this, that the *former* is seen from the surface of the earth, and the *latter* is

* See Dr. Ashworth's Trigonometry, Proposition 34, second edition, 1803.

supposed to be viewed from its centre.

Tutor. You are right; and the rising and setting of the sun and stars are always referred to the *rational* horizon.

James. Why so? they appear to rise and set as soon as they get above, or sink below that boundary which separates the visible from the invisible parts of the heavens.

Tutor. They do not, however: and the reason is this, that the distance of the sun and fixed stars is so great in comparison of 4000 miles (the difference between the surface and centre of the earth), that it can scarcely be taken into account.

Charles. But 4000 miles seem to me an immense space.

Tutor. Considered separately, they are so, but when compared with 95 millions of miles, the distance of the sun from the earth, they almost vanish as nothing.

James. But do the rising and setting of the moon, which is at the distance of 240 thousand miles only, respect also the rational horizon?

Tutor. Certainly; for 4000 compared with 240 thousand, bear only the proportion of 1 to 60. Now if two spaces were marked out on the earth in different directions, the one 60 and the other 61 yards, should you at once be able to distinguish the greater from the less?

Charles. I think not.

Tutor. Just in the same manner does the distance of the centre from the surface of the earth vanish in

comparison of its distance from the moon.

James. We must not, however, forget the succession of day and night.

Tutor. Well then; if the sun be supposed at Z, it will illuminate, by its rays, all that part of the earth that is above the horizon H O. To the inhabitants at G, its western boundary, it will appear just rising; to those situated at R, it will be noon; and to those in the eastern part of the horizon C, it will be setting.

Charles. I see clearly why it should be noon to those who live at R, because the sun is just over their heads, but it is not so evident, why the sun must appear rising and setting to those who are at G and C.

Tutor. You are satisfied that a spectator cannot, from any place, observe more than a semicircle of the heavens at any one time; now what part of the heavens will the spectator at G observe?

James. He will see the concave hemisphere Z O N.

Tutor. The boundary to his view will be N and Z, will it not?

Charles. Yes; and consequently the sun, at Z, will to him be just coming into sight.

Tutor. Then, by the rotation of the earth, the spectator at G will in a few hours come to R, when, to him, it will be noon; and those, who live at R, will have descended to C; now what part of the heavens will they see in this situation?

James. The concave hemisphere

N H Z, and Z being the boundary of their view one way, the sun will to them be setting.

Tutor. Just so. After which they will be turned away from the sun, and consequently it will be night to them till they come again to G. Thus, by this simple motion of the earth on its axis, every part of it is, by turns, enlightened and warmed by the cheering beams of the sun.

Charles. Does this motion of the earth account also for the apparent motion of the fixed stars?

Tutor. It is owing to the revolution of the earth round its axis, that we imagine the whole starry firmament revolves about the earth in 24 hours.

James. If the heavens appear to

turn on an axis, must there not be two points, namely, the extremities of that imaginary axis, which always keep their position?

Tutor. Yes, we must be understood to except the two celestial poles, which are opposite to the poles of the earth; consequently each fixed star appears to describe a greater or a less circle round these, according as it is more or less remote from those celestial poles.

Charles. When we turn from that hemisphere in which the sun is placed we immediately gain sight of the other in which the stars are situated.

Tutor. Every part of the heaven is decorated with these glorious bodies: and

Night opes the noblest scenes, and sheds an awe,
Which gives those venerable scenes full weight,
And deep reception in th' intender'd heart.
This gorgeous apparatus! This display!
This ostentation of creative power!
This theatre! what eye can take it in?
By what divine enchantment was it rais'd
For minds of the first magnitude to launch
In endless speculation, and adore?
One sun by day, by night ten thousand shine,
And light us deep into the Deity;
How boundless in magnificence and might!

YOUNG.

James. If every part of the heavens be thus adorned, why do we not see the stars in the day as well as the night?

Tutor. Because in the day time the sun's rays are so powerful as to render *those* coming from the fixed stars invisible. But if you ever

happen to go down into any very deep mine, or coal-pit, where the rays of the sun cannot reach the eye, and it be a clear day, you may, by looking up to the heavens, see the stars at noon as well as in the night.

Charles. If the earth always revolve on its axis in 24 hours, why does the length of the days and nights differ in different seasons of the year?

Tutor. This depends on other causes connected with the earth's *annual* journey round the sun, upon which we will converse the next time we meet.

CONVERSATION IX.

Of the Annual Motion of the Earth.

TUTOR. Besides the *diurnal* motion of the earth, by which the succession of day and night is produced, it has another, called its *annual* motion, which is the journey it performs round the sun in 365 days, 5 hours, 48 minutes, and 49 seconds.

Charles. Are the different seasons to be accounted for by this motion of the earth?

Tutor. Yes, it is the cause of the different lengths of the days and

nights, and consequently of the different seasons, *viz*. *Spring*, *Summer*, *Autumn*, and *Winter*.

It shifts the seasons, months, and days,
The short-liv'd offspring of revolving time;
By turns they die, by turns are born.
Now cheerful Spring the circle leads
And strews with flow'rs the smiling meads.
Gay Summer next, whom russet robes adorn,
And waving fields of yellow corn.
Then Autumn, who with lavish stores the lap
    of Nature spreads.
Decrepit Winter, laggard in the dance
(Like feeble age opprest with pain),
A heavy season does maintain,
With driving snows and winds and rain;
Till Spring, recruited to advance,
The various year rolls round again.

HUGHES.

James. How is it known that the earth makes this annual journey round the sun?

Tutor. I told you yesterday, that, through the shaft of a very deep mine, the stars are visible in the day as well as in the night; they are also visible in the day time, by means of a telescope properly fitted up for the purpose; by this method, the sun and stars are visible at the same time. Now if the sun be seen in a line with a fixed star, to-day at any particular hour, it will, in a few weeks, by the motion of the earth, be found considerably to the east of him: and if the observations be continued through the year, we shall be able to trace him round the heavens to the same fixed star from which we set out; consequently, the sun must have made a journey round the earth in that time, or the earth round him.

Charles. And the sun being a million of times larger than the earth, you will say that it is more natural, that the smaller body should go round the larger, than the reverse.

Tutor. That is a proper argument: but it may be stated in a much stronger manner. The sun and earth mutually attract one another, and since they are *in equilibrio* by this attraction, you know, their momenta must be equal*, therefore the earth being the smaller body, makes out by its motion what it wants in the quantity of its matter, and, of course, it is that which performs the journey.

James. But if you refer to the principle of the lever, to explain the

* See Vol. I, Conversation XIV, p. 121.

mutual attraction of the sun and earth, it is evident, that both bodies must turn round some point as a common centre.

Tutor. They do; and that is the common centre of gravity of the two bodies. Now this point between the earth and sun is within the surface of the latter body.

Charles. I understand how this is: because the centre of gravity between any two bodies, will be as much nearer to the centre of the larger body than to that of the smaller, as the former contains a greater quantity of matter than the latter.

Tutor. You are right: but you will not conclude that, because the sun is a million of times larger than the earth, therefore it contains a quantity of matter a million of

times greater than that contained in the earth.

James. Is it then known, that the earth is composed of matter more dense than that which composes the body of the sun?

Tutor. The earth is composed of matter four times denser than that of the sun; and hence the quantity of matter in the sun is between two and three hundred thousand times greater than that which is contained in the earth.

Charles. Then for the momenta of these two bodies to be equal, the velocity of the earth must be between two and three hundred thousand times greater than that of the sun.

Tutor. Just so: and to effect this, the centre of gravity between the sun and earth will be as much

nearer to the centre of the sun than it is to the centre of the earth, as the former body contains a greater quantity of matter than the latter: and hence it is found to be several thousand miles within the surface of the sun.

James. I now clearly perceive, that since one of these bodies revolves about the other in the space of a year, and that they both move round their common centre of gravity, that it must of necessity be the earth which revolves about the sun, and not the sun round the earth.

Tutor. Your inference is just. To suppose that the sun moves round the earth is as absurd as to maintain, that a mill-stone could be made to move round a pebble.

CONVERSATION X.

Of the Seasons.

TUTOR. I will now show you how the different seasons are produced by the annual motion of the earth.

James. Upon what do they depend, Sir?

Tutor. The variety of the seasons depends (1) upon the length of the days and nights, and (2) upon the position of the earth with respect to the sun.

Charles. But if the earth turn round its imaginary axis every 24

hours, ought it not to enjoy equal days and nights all the year?

Tutor. This would be the case if the axis of the earth N S (Plate II, Fig. 6) were perpendicular to a line C E drawn through the centres of the sun and earth; for then, as the sun always enlightens one half of the earth by its rays, and as it is day at any given place on the globe, so long as that place continues in the enlightened hemisphere, every part, except the two poles, must, during its rotation on its axis, be one half of its time in the light and the other half in darkness: or, in other words, the days and nights would be equal to all the inhabitants of the earth, excepting to those, if any, who live at the poles.

James. Why do you except the people at the poles?

Tutor. Because the view of the spectator situated at the poles N and S, must be bounded by the line C E; consequently, to him the sun would never appear to rise or set, but would always be in the horizon.

Charles. If the earth were thus situated, would the rays of the sun always fall vertically on the same part of it?

Tutor. They would: and that part would be E Q the equator; and, as we shall presently show, the heat excited by the sun being greater or less in proportion as its rays come more or less perpendicularly upon any body, the parts of the earth about the equator would be scorched

up, while those beyond 40 or 50 degrees on each side of that line and the poles would be desolated by an unceasing winter.

——— Some say the sun
Was bid turn reins from th' *equinoctial* road
Up to the *Tropic Crab*; thence down amain
By *Leo*, and the *Virgin*, and the *Scales*,
As deep as *Capricorn*, to bring in change
Of seasons to each clime: else had the spring
Perpetual smil'd on earth with vernant flowers,
Equal in days and nights, except to those
Beyond the *polar* circles: to them day
Had unbenighted shone, while the low sun
To recompense his distance, in their sight
Had rounded still th' horizon.

PAR. LOST, Book x, l. 672.

James. In what manner is this prevented?

Tutor. By the axis of the earth N S (Plate II, Fig. 7) being inclined or bent about 23 degrees and a half

out of the perpendicular, as it is described by Milton:—

———— He bid his angels turn askance
The poles of earth twice ten degrees and more
From the sun's axle.

In this case you observe, that all the parallel circles, except the equator, are divided into two unequal parts, having a greater or less portion of their circumferences in the enlightened than in the dark hemisphere, according to their situation with respect to N the north, or S the south pole.

Charles. At what season of the year is the earth represented in this figure?

Tutor. At our summer season; for you observe that the parallel circles in the northern hemisphere have

their greater parts enlightened and their smaller parts in the dark. If D L represent that circle of latitude on the globe in which Great Britain is situated, it is evident that about two thirds of it is in the light, and only one third in darkness.

You will remember, that *parallels of latitude* are supposed circles on the surface of the earth, and are shown by real circles on its representative the terrestrial globe, drawn parrallel to the equator.

James. Is that the reason why our days towards the middle of June are 16 hours long, and the nights but 8 hours?

Tutor. It is: and if you look to the parallel next beyond that marked D L, you will see a still greater disproportion between the day and

night, and the parallel more north than this is entirely in the light.

Charles. Is it then all day there?

Tutor. To the whole space between that and the pole it is continual day for some time, the duration of which is in proportion to its vicinity to the pole; and at the pole there is a permanent daylight for six months together.

James. And during that time it must I suppose be night to the people who live at the south pole?

Tutor. Yes, the figure shows that the south pole is in darkness; and you may observe, that to the inhabitants living in equal parallels of latitude, the one north and the other south, the length of the days to the one will be always equal to the ength of the nights to the other.

Charles. What then shall we say to those who live at the equator, and consequently who have no latitude?

Tutor. To them the days and nights are *always* equal, and of course twelve hours each in length, and this is also evident from the figure, for in every position of the globe one half of the equator is in the light and the other half in darkness.

James. If, then, the length of the days is the cause of the different seasons, there can be no variety, in this respect, to those who live at the equator?

Tutor. You seem to forget that the change in the seasons depends upon the position of the earth with respect to the sun, that is, upon the *perpendicularity* with which the rays

of light fall upon any particular part of the earth, as well as upon the length of the days.

Charles. Does this make any material difference with regard to the heat of the sun?

Tutor. It does: let A B (Plate II, Fig. 8) represent a portion of the earth's surface on which the sun's rays fall perpendicularly; let B C represent an equal portion on which they fall obliquely or aslant. It is manifest that B C, though it be equal to A B, receives but half the light and heat that A B does. Moreover, by the sun's rays coming more perpendicularly, they come with greater force, as well as in greater numbers, on the same place.

CONVERSATION XI.

Of the Seasons.

TUTOR. Let us now take a view of the earth in its annual course round the sun, considering its axis as inclined $23\frac{1}{2}$ degrees to a line perpendicular to its orbit, and keeping, through its whole journey, a direction parallel to itself; and you will find, that, according as the earth is in different parts of its orbit, the rays of the sun are presented perpendicularly to the equator, and to every point of the

globe, within $23\frac{1}{2}$ degrees of it both north and south.

This figure (Plate II, Fig. 9) represents the earth in four different parts of its orbit, or as it is situated with respect to the sun in the months of March, June, September, and December.

Charles. The earth's orbit is not made circular in the figure.

Tutor. No; but the orbit itself is nearly circular: we are, however, supposed to view it from the side B D, and therefore, though almost a circle, it appears to be a long ellipse. All circles appear elliptical in an oblique view, as is evident by looking obliquely at the rim of a bason at some distance from you. For the true figure of a circle can only be seen when the eye is directly over its

centre. You observe that the sun is not in the centre.

James. I do; and it appears nearer to the earth in the winter than in the summer.

Tutor. We are indeed more than three millions of miles nearer to the sun in December than we are in June.

Charles. Is this possible, and yet our winter is so much colder than the summer?

Tutor. Notwithstanding this, it is a well known fact: for it is ascertained that our summer, that is, the time that passes between the vernal and autumnal equinoxes, is nearly eight days longer than our winter, or the time between the autumnal and vernal equinoxes. Consequently the motion of the earth is slower in the former case than in the

latter, and therefore, as we shall see, it must be at a greater distance from the sun. Again, the sun's *apparent* diameter is greater in our winter than in summer; but the apparent diameter of any object increases in proportion as our distance from the object is diminished, and therefore we conclude, that we are nearer the sun in winter than in summer. The sun's apparent diameter in winter is $32'.47''$; in summer $31'.40''$.

James. But if the earth is farther from the sun in summer than in winter, why are our winters so much colder than our summers?

Tutor. Because first, in the summer, the sun rises to a much greater height above our horizon, and therefore, its rays coming more perpendicularly, a greater number of them,

as we showed you yesterday, must fall upon the surface of the earth, and they come also with greater force, which is the principal cause of our great summer's heat. Secondly, in the summer, the days are very long, and the nights short; therefore the earth and air are heated by the sun in the day more than they are cooled in the night.

James. Why have we not, then, the greatest heat at the time when the days are longest.

Tutor. The hottest season of the year is certainly a month or two after this, which may be thus accounted for. A body once heated does not grow cold again instantaneously, but gradually; now, as long as more heat comes from the sun in the day than is lost in the

night, the heat of the earth and air will be daily increasing, and this will evidently be the case for some weeks after the longest day, both on account of the number of rays which fall on a given space, and also from the perpendicular direction of those rays.

James. Will you now explain to us in what manner the seasons are produced?

Tutor. By referring to the figure (Plate II, Fig. 9) you will observe, that in the month of June, the north pole of the earth inclines towards the sun, and consequently brings all the northern parts of the globe more into light than at any other time in the year.

Charles. Then to the people in those parts it is summer?

Tutor. It is: but in December, when the earth is in the opposite part of its orbit, the north pole declines from the sun, which occasions the northern places to be more in the dark than in the light; and the reverse at the southern places.

James. Is it then summer to the inhabitants of the southern hemisphere?

Tutor. Yes, it is; and winter to us. In the months of March and September, the axis of the earth does not incline to, nor decline from the sun, but is perpendicular to a line drawn from its centre. And then the poles are in the boundary of light and darkness, and the sun being directly vertical to, or over the equator, makes equal day and night at all places. Now trace the

annual motion of the earth in its orbit for yourself, as it is represented in the figure.

Charles. I will, Sir; about the 20th of March the earth is in Libra, and consequently to its inhabitants the sun will appear in Aries, and be vertical to the equator.

Tutor. Then the equator and all its parallels are equally divided between the light and dark.

Charles. Consequently the days and nights are equal all over the world. As the earth pursues its journey from March to June, its northern hemisphere comes more into light, and on the first of that month, the sun is vertical to the tropic of Cancer.

Tutor. You then observe, that all the circles parallel to the equator

are unequally divided; those, in the northern half, have their greater parts in the light, and those, in the southern half, have their larger parts in darkness.

Charles. Yes; and, of course, it is summer to the inhabitants of the northern hemisphere, and winter to the southern.

I now trace it to September, when I find the sun vertical again to the equator, and, of course, the days and nights are again equal. And following the earth in its journey to December, or when it has arrived at Cancer, the sun appears in Capricorn, and is vertical to that part of the earth called the tropic of Capricorn, and now the southern pole is enlightened, and all the circles on that hemisphere have their larger

parts in light, and, of course, it is summer to those parts, and winter to us in the northern hemisphere.

Tutor. Can you, James, now tell me why the days lengthen and shorten from the equator to the polar circles every year?

James. I will try to explain myself on the subject. Because the sun in March is vertical to the equator, and from that time to the 21st of June it becomes vertical successively to all other parts of the earth between the equator and the tropic of Cancer, and in proportion as it becomes vertical to the more northern parts of the earth, it declines from the southern, and, consequently, to the former the days lengthen, and to the latter they shorten. From June to September the sun is again

vertical successively to all the same parts of the earth, but in a reverse order.

Charles. Since it is summer to all those parts of the earth where the sun is vertical, and we find that the sun is vertical twice in the year to the equator, and every part of the globe between the equator and tropics, there must be also two summers in a year to all those places.

Tutor. There are; and in those parts near the equator they have two harvests every year.—But let your brother finish his description.

James. From September to December, it is successively vertical to all the parts of the earth situated between the equator and the tropic of Capricorn, which is also the cause of the lengthening of the days

in the southern hemisphere, and of their becoming shorter in the northern.

Tutor. Can you, Charles, tell me why there is sometimes no day or night for some little time together within the polar circles?

Charles. The sun always shines upon the earth 90 degrees every way, and when he is vertical to the tropic of Cancer, which is $23\frac{1}{2}$ degrees north of the equator, he must shine the same number of degrees beyond the pole, or to the polar circle, and while he thus shines, there can be no night to the people within that polar circle, and, of course, to the inhabitants at the southern polar circle there can be no days at the same time, for as the sun's rays reach but 90 degrees every

way, they cannot shine far enough to reach them.

Tutor. Tell me, now, why there is but one day and night in the whole year at the poles.

Charles. For the reason which I have just given, the sun must shine beyond the north pole all the time he is vertical to those parts of the earth situated between the equator and the tropic of Cancer, that is, from March the 21st to September the 20th, during which time there can be no night at the north pole, nor any day at the south pole. The reverse of this may be applied to the southern pole.

James. I understand now, that the lengthening and shortening of the days, and different seasons, are produced by the annual motion of

the earth round the sun; the axis of the earth, in all parts of its orbit, being kept parallel to itself.

Tutor. Yes, I think you see the reason very distinctly, why the days lengthen and shorten from the equator to the polar circles every year—why there is sometimes no day or night for some time together within the polar circles—why there is but one day and one night in the whole year at the poles—and why the days and nights are equally long all the year round at the equator.

Charles. But if the axis of the earth is thus parallel to itself, how can it in all positions point to the pole star in the heavens?

Tutor. Because the diameter of the earth's orbit A C is nothing in comparison of the distance of the

earth from the fixed stars. Suppose you draw two parallel lines, at the distance of three or four yards from one another, will they not both point to the moon when she is in the horizon?

James. Three or four yards cannot be accounted as any thing, in comparison of 240 thousand miles, the distance of the moon from us.

Tutor. Perhaps three yards bear a much greater proportion to 240 thousand miles, than 190 millions of miles bear to our distance from the polar star.

CONVERSATION XII.

Of the Equation of Time.

TUTOR. You are now, I presume, acquainted with the motions peculiar to this globe on which we live?

Charles. Yes; it has a rotation on its axis from west to east every 24 hours, by which day and night are produced, and also the apparent diurnal motion of the heavens from east to west.

James. The other is its annual revolution in an orbit round the sun, likewise from west to east, at the

distance of about 95 millions of miles from the sun.

Tutor. You understand, also, in what manner this annual motion of the earth, combined with the inclination of its axis, is the cause of the variety of seasons*.

We will therefore proceed to investigate another curious subject, *viz.* the equation of time, and to explain to you the difference between *equal* and apparent time.

* The inclination of an axis or orbit is merely relative, because we compare it with some other axis or orbit which is supposed to have no inclination. Thus the horizon at London, or at any other place where we live, being level to us, we regard it as having no inclination; but if we set out and travel 90 degrees from that place our horizon then will be perpendicular to the horizon of London.

Charles. Will you tell us what you mean by the words *equal* and *apparent*, as applied to time?

Tutor. *Equal* time is measured by a clock, that is supposed to go without any variation, and to measure exactly 24 hours from noon to noon. And *apparent* time is measured by the *apparent* motion of the sun in the heavens, or by a good sun-dial.

Charles. And what do you mean, Sir, by the *equation of time?*

Tutor. It is the adjustment of the difference of time, as shown by a well-regulated clock and a true sun-dial.

James. Upon what does this difference depend?

Tutor. It depends, *first*, upon the inclination of the earth's axis; and,

secondly, upon the elliptic form of the earth's orbit: for as we have already seen, the earth's orbit being an ellipse, its motion is quicker when it is in *perihelion*, or nearest to the sun; and slower when it is in *aphelion*, or farthest from the sun.

Charles. But I do not yet comprehend what the rotation of the earth has to do with the going of a clock or watch.

Tutor. The rotation of the earth is the most equable and uniform motion in nature, and is completed in 23 hours, 56 minutes, and 4 seconds; this space of time is called a *sidereal* day, because any meridian on the earth will revolve from a fixed star to that star again in this time. But a *solar* or natural day, which our clocks are intended to measure, is

the time which any meridian on the earth will take in revolving from the sun to the sun again, which is about 24 hours, sometimes a little more, but generally less.

James. What occasions this difference between the solar and sidereal day?

Tutor. The distance of the fixed stars is so great, that the diameter of the earth's orbit, though 190 millions of miles, when compared with it, is but a point, and therefore any meridian on the earth will revolve from a fixed star to that star again in exactly the same time, as if the earth had only a diurnal motion, and remained always in the same part of its orbit. But with respect to the sun, as the earth advances almost a degree eastward in its orbit, in the

same time that it turns eastward round its axis, it must make more than a complete rotation before it can come into the same position with the sun that it had the day before. In the same way, as when both the hands of a watch or clock set off together at twelve o'clock, the minute hand must travel more than a whole circle before it will overtake the hour hand; that is, before they will be in the same relative position again. Thus the sidereal days are shorter than the solar ones by about four minutes, as is evident from observation: —

Watch with nice eye the earth's diurnal way,
Marking her *solar* and *sidereal* day;
Her slow nutation, and her varying clime,
And trace with mimic art the march of time.

BOTANICAL GARDEN.

Charles. Still I do not understand

the reason why the clocks and dials do not agree.

Tutor. A good clock is intended to measure that equable and uniform time which the rotation of the earth on its axis exhibits; whereas the dial measures time by the *apparent* motion of the sun, which, as we have explained, is subject to variation. Or thus: though the earth's motion on its axis be perfectly uniform, and consequently the rotation of the *equator*, the plane of which is perpendicular to the axis, or of any other circle parallel to it be likewise equable, yet we measure the length of the natural day by means of the sun, whose *apparent* annual motion is not in the equator, or any of its parallels, but in the ecliptic, which is oblique to it?

James. Do you mean by this, that

the equator of the earth, in its annual journey, is not always directed towards the centre of the sun?

Tutor. I do: twice only in the year, a line drawn from the centre of the sun to that of the earth passes through those points where the equator and ecliptic cross one another; at all other times, it passes through some other part of that oblique circle, which is represented on the globe by the ecliptic line. Now when it passes through the equator or the tropics, which are circles parallel to the equator, the sun and clocks go together, as far as regards this cause; but at other times they differ, because *equal* portions of the ecliptic pass over the meridian in *unequal* parts of time on account of its obliquity.

Charles. Can you explain this by a figure?

Tutor. It is easily shown by the globe, which this figure ♈ N ♎ S (Plate II, Fig. 10) may represent; ♈ ♎ will be the equator, ♈ ♋ ♎ the northern half of the ecliptic, and ♈ ♑ ♎ the southern half. Make chalk or pencil marks *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, all round the *equator* and *ecliptic*, at equal distances (suppose 20 degrees) from each other, beginning at Aries. Now by turning the globe on its axis, you will perceive that all the marks in the first quadrant of the *ecliptic*, that is, from Aries to Cancer, come *sooner* to the brazen meridian than their corresponding marks on the *equator*:—those from the beginning of Cancer to Libra come *later*:—those from Libra to Capricorn sooner:—

and those from Capricorn to Aries later.

Now time as measured by the sun-dial is represented by the marks on the *ecliptic*; that measured by a good clock, by those on the equator.

Charles. Then while the sun is in the first and third quarters, or, what is the same thing, while the earth is travelling through the second and fourth quarters, that is, from Cancer to Libra, and from Capricorn to Aries, the sun is faster than the clocks, and while it is travelling the other two quarters it is slower.

Tutor. Just so: because, while the earth is travelling through the second and fourth quadrants, equal portions of the ecliptic come *sooner* to the meridian than their corre-

sponding parts of the equator: and during its journey through the first and third quadrants, the equal parts of the ecliptic arrive *later* at the meridian than their corresponding parts of the equator.

James. If I understand what you have been saying, the dial and clocks ought to agree at the equinoxes, that is, on the 20th of March, and the 23d of September; but if I refer to the Ephemeris, I find that on the former day (1809) the clock is 8 minutes before the sun; and on the latter day the clock is almost 8 minutes behind the sun.

Tutor. If this difference between time measured by the dial and clock depended only on the inclination of the earth's axis to the plane of its orbit, the clocks and dial ought to

be together at the equinoxes, and also on the 21st of June and the 21st of December, that is, at the summer and winter solstices; because, on those days, the *apparent* revolution of the sun is parallel to the equator. But I told you there was another cause why this difference subsisted.

Charles. You did: and that was the elliptic form of the earth's orbit.

Tutor. If the earth's motion in its orbit were uniform, which it would be if the orbit were circular, then the whole difference between *equal* time as shown by the clock, and *apparent* time as shown by the sun, would arise from the inclination of the earth's axis. But this is not the case, for the earth travels, when it is nearest the sun, that is, in the

winter, more than a degree in 24 hours, and when it is farthest from the sun, that is, in summer, less than a degree in the same time: consequently from this cause the natural day would be of the greatest length when the earth was nearest the sun, for it must continue turning the longest time after an entire rotation, in order to bring the meridian of any place to the sun again; and the shortest day would be when the earth moves the slowest in her orbit. Now these inequalities, combined with those arising from the inclination of the earth's axis, make up that difference which is shown by the equation table, found in the Ephemeris, between good clocks and true sun-dials.

CONVERSATION XIII.

Of Leap-Year.

JAMES. Before we quit the subject of time, will you give us some account of what is called in our Almanacs Leap-year?

Tutor. I will. The length of our year is, as you know, measured by the time which the earth takes in performing her journey round the sun, in the same manner as the length of the day is measured by its rotation on its axis. Now, to compute the exact time taken by the earth in its annual journey, was a

work of considerable difficulty. Julius Cæsar was the first person who seems to have attained to any accuracy on this subject.

Charles. Do you mean the first Roman emperor, who landed also in Great Britain?

Tutor. I do. He was not less celebrated as a man of science, than he was renowned as a general: of him it was said,

Amidst the hurry of tumultuous war,
The stars, the gods, the heav'ns were still his care,
Nor did his skill to fix the rolling year
Inferior to Eudoxus' art appear.

Julius Cæsar, who was well acquainted with the learning of the Egyptians, fixed the length of the year to be 365 days and 6 hours, which made it six hours longer than the

Egyptian year. Now, in order to allow for the odd 6 hours in each year, he introduced an additional day every fourth year, which accordingly consists of 366 days, and is called *Leap*-Year, while the other three have only 365 days each. From him it was denominated the *Julian* year.

James. It is also called *Bissextile* in the Almanacs, what does that mean?

Tutor. The Romans inserted the intercalary day between the 23d and 24th of February: and because the 23d of February, in their calendar, was called *sexto calendas Martii*, the 6th of the calends of March, the intercalated day was called *bis sexto calendas Martii*, the second sixth of the calends of March, and hence the year of intercalation had the appellation of *Bissextile.* This day was chosen at

Rome, on account of the expulsion of Tarquin from the throne, which happened on the 23d of February. We introduce, in Leap-Year, a new day in the same month, namely, the 29th.

Charles. Is there any rule for knowing what year is Leap-Year?

Tator. It is known by dividing the date of the year by 4, if there be no remainder, it is Leap-Year; thus 1815 divided by 4, leaves a remainder of 3, showing that it is the third year after Leap-Year. These two lines contain the rule:

> Divide by 4; what's left, shall be
> For Leap-year 0; for past 1, 2, 3.

James. The year, however, does not consist of 365 days and 6 hours, but of 365 days, 5 hours, 48 minutes,

and 49 seconds*. Will not this occasion some error?

Tutor. It will: and by subtracting the latter number from the former, you will find that the error amounts to 11 minutes and 11 seconds every year, or to a whole day in about 130 years: notwithstanding this, the Julian year continued to be in general use till the year 1582, when Pope Gregory XIII undertook to rectify the error, which at that time amounted to ten days. He accordingly commanded the ten days between the 4th and 15th of October in that year to be suppressed, so that the 5th day of that month was called the 15th. This alteration took place through the greater part of Europe, and the year was afterwards

* See Conversation IX.

called the Gregorian year, or *New Style*. In this country, the method of reckoning, according to the New Style, was not admitted into our calendars until the year 1752, when the error amounted to nearly 11 days, which were taken from the month of September, by calling the 3d of that month the 14th.

Charles. By what means will this accuracy be maintained?

Tutor. The error amounting to one whole day in about 130 years, it is settled by an act of parliament, that the year 1800 and the year 1900, which are, according to the rule just given, Leap-Years, shall be computed as common years, having only 365 days in each: and that every *four* hundredth year afterwards shall be a common year also. If this method

be adhered to, the present mode of reckoning will not vary a single day from true time, in less than 5000 years.

By the same act of parliament, the legal beginning of the year was changed from the 25th of March to the 1st of January. So that the succeeding months of January, February, and March, up to the 24th day, which would, by the Old Style, have been reckoned part of the year 1752, were accounted as the first three months of the year 1753. Hence we sometimes see such a date as this, Feb. 10, 1774-5, that is, according to the Old Style it was 1774, but according to the New it is 1775, because now the year begins in January instead of March.

CONVERSATION XIV.

Of the Moon.

TUTOR. You are now, gentlemen, acquainted with the reasons for the division of time into days and years.

Charles. These divisions have their foundation in nature, the *former* depending upon the rotation of the earth on its axis; the *latter* upon its revolution in an elliptic orbit about the sun as a centre of motion.

James. Is there any natural reason for the division of years into

weeks, or of days into hours, minutes, and seconds?

Tutor. These divisions were invented entirely for the convenience of mankind, and are accordingly different in different countries. There is, however, another division of time marked out by nature.

Charles. What is that, Sir?

Tutor. The length of the *month*: not indeed that month which consists of four weeks, nor that by which the year is divided into 12 parts. These are both arbitrary. But by a month is meant the time which the moon takes in performing her journey round the earth:—

> Then mark'd astronomers with keener eyes
> The moon's refulgent journey through the skies.
>
> DARWIN.

James. How many days does the moon take for this purpose?

Tutor. If you refer to the time in which the moon revolves from one point of the heavens to the same point again, it consits of 27 days, 7 hours, and 43 minutes; this is called the *periodical* month: but if you refer to the time passed from new moon to new moon again, the month consists of 29 days, 12 hours, and 44 minutes; this is called the *synodical* month.

Charles. Pray explain the reason of this difference.

Tutor. It is occasioned by the earth's annual motion in its orbit. Let us refer to our watch as an example. The two hands are together at 12 o'clock; now, when the minute-hand has made a complete revolution, are they together again?

James. No; for the hour-hand is advanced the twelfth part of its revolution, which, in order that the other may overtake, it must travel five minutes more than the hour.

Tutor. And something more, for the hour-hand does not wait, at the figure I, till the other comes up: and therefore they will not be together till between 5 and 6 minutes after one.

Now apply this to the earth and moon, suppose (Plate III, Fig. 11) S to be the sun; T the earth, in a part of its orbit Q L; and E to be the position of the moon: if the earth had no motion, the moon would move round its orbit E H C into the position E again, in 27 days, 7 hours, 43 minutes; but while the moon is describing her journey, the earth has

passed through nearly a twelfth part of its orbit, which the moon must also describe before the two bodies come again into the same position that they before held with respect to the sun: this takes up so much more time as to make her synodical month equal to 29 days, 12 hours, and 44 minutes: hence the foundation of the division of time into months.

We will now proceed to describe some other particulars relating to the moon, as a body depending, like the earth, on the sun for her light and heat.

Charles. Does the moon shine with a borrowed light only?

Tutor. This is certain; for otherwise, if, like the sun, she were a luminous body, she would always shine with a full orb as the sun does:—

——— Less bright the moon,
But opposite in levell'd west was set,
His mirror, with full face *borrowing* her light
From him, for other light she needed none.

Her diameter is nearly 2200 miles in length.

James. And I remember she is at the distance of 240,000 miles from the earth.

Tutor. The sun S (Plate III, Fig. 11) always enlightens one half of the moon E, and its whole enlightened hemisphere, or a part of it, or none at all, is seen by us according to her different positions in the orbit with respect to the earth; for only those parts of the enlightened half of the moon are visible at T which are cut off by, and are *within* the orbit.

James. Then when the moon is at

E, no part of its enlightened side is visible to the earth.

Tutor. You are right: it is then *new* moon, or *change*, for it is usual to call it new moon the first day it is visible to the earth, which is not till the second day after the change. And the moon being in a line between the sun and earth, they are said to be in *conjunction*.

Charles. And at A all the illuminated hemisphere is turned to the earth.

Tutor. This is called *full* moon; and the earth being between the sun and moon, they are said to be in *opposition*. The enlightened parts of the little figures on the outside of the orbit, represent the appearance of the moon as seen by a spectator on the earth.

James. Is the little figure then opposite E wholly dark to show that the moon is invisible at *change?*

Tutor. It is: and when it is at F a small part of the illuminated hemisphere is *within* the moon's orbit, and therefore to a spectator on the earth it appears *horned;* at G one half of the enlightened hemisphere is visible, and it is said to be in *quadrature:* at H three-fourths of the enlightened part is visible to the earth, and it is then said to be *gibbous:* and at A the whole enlighted face of the moon is turned to the earth, and it is said to be *full.* The same may be said of the rest.

The horns of the moon, before conjunction or new moon, are turned to the *east:* after conjunction they are turned to the *west.* How beautifully is the moon described by Milton:—

——————till the moon,
Rising in clouded majesty, at length,
Apparent Queen, unveil'd her peerless light,
And o'er the dark her silver mantle threw.
Book iv, line 606.

Charles. I see the figure is intended to show that the moon's orbit is elliptical: does she also turn upon her axis?

Tutor. She does; and she requires the same time for her diurnal rotation, as she takes in completing her revolution about the earth; and consequently, though every part of the moon is successively presented to the sun, yet the same hemisphere is always turned to the earth. This is known by observation with good telescopes.

James. Then the length of a day and night in the moon is equal to more than 29 days and a half of ours.

Tutor. It is so: and therefore, as the length of her year, which is measured by her journey round the sun, is equal to that of ours, she can have but about twelve days and one third in a year. Another remarkable circumstance relating to the moon is, that the hemisphere next the earth is never in darkness, for in the position E, when it is turned from the sun, it is illuminated by light reflected from the earth in the same manner as we are enlightened by a full moon. But the other hemisphere of the moon has a fortnight's light and darkness by turns.

Charles. Can the earth, then, be considered as a satellite to the moon?

Tutor. It would, perhaps, be inaccurate to denominate the larger body a satellite to the smaller; but,

with regard to affording reflected light, the earth is to the moon what the moon is to the earth, and subject to the same changes of horned, gibbous, full, &c.

Charles. But it must appear much larger than the moon.

Tutor. The earth will appear, to the inhabitants of the moon, about 13 times as large as the moon appears to us. When it is *new moon* to us, it is *full earth* to them, and the reverse.

James. Is the moon then inhabited as well as the earth?

Tutor. Though we cannot demonstrate this fact, yet there are many reasons to induce us to believe it: for the moon is a secondary planet of considerable size;—its surface is diversified like that of the earth with mountains and valleys;—the

former have been measured by Dr. Herschel, and some of them found to be about a mile in height. The situation of the moon, with respect to the sun, is much like that of the earth, and by rotation on her axis, and a small inclination on that axis to the plane of her orbit, she enjoys, though not a considerable, yet an agreeable variety of day and night and of seasons. To the moon, our globe appears a capital satellite, undergoing the same changes of illumination as the moon does to the earth. The sun and stars rise and set there as they do here, and heavy bodies will fall on the moon as they do on the earth. Hence we are led to conclude that, like the earth, the moon also is inhabited. Dr. Herschel discovered some years ago three volcanoes, all

burning in the moon; two of them appeared to him nearly extinct, but the third showed an actual eruption of fire or luminous matter. He thought the eruption resembled a small piece of burning charcoal when it is covered by a thin coat of white ashes, which frequently adhere to it, when it has been ignited some time. But no large seas or tracts of water have been observed in the moon, nor is the existence of a lunar atmosphere certain. Therefore, her inhabitants must materially differ from those who live upon the earth.

CONVERSATION XV.

Of Eclipses.

CHARLES. Will you, Sir, explain to us the nature and causes of eclipses?

Tutor. I will, with great pleasure. You must observe, then, that eclipses depend upon this simple principle, that all opaque or dark bodies, when exposed to any light, and therefore to the light of the sun, cast a shadow behind them in an opposite direction.

James. The earth, being a body of this kind, must cast a very large

shadow on its side which is opposite to the sun.

Tutor. It does: and an eclipse of the moon happens when the earth T (Plate III, Fig. 12) passes between the sun S and the moon M, and it is occasioned by the earth's shadow being cast on the moon.

Charles. When does this happen?

Tutor. It is only when the moon is full, or in *opposition*, that it comes within the shadow of the earth.

James. Eclipses of the moon, however, do not happen every time it is full: what is the reason of this?

Tutor. Because the orbit of the moon does not coincide with the plane of the earth's orbit, but one half of it is elevated about five de-

grees and a third above it, and the other half is as much below it: and therefore, unless the full moon happen in or near one of the nodes, that is, in or near the points in which the two orbits intersect each other, she will pass above, or below the shadow of the earth, in which case there can be no eclipse.

Charles. What is the greatest distance from the node, at which an eclipse of the moon can happen?

Tutor. There can be no eclipse, if the moon, at the time when she is full, be more than 12 degrees from the node; when she is within that distance, there will be a *partial* or *total* eclipse, according as a part, or the whole disk or face of the moon falls within the earth's shadow. If the eclipse happen exactly when the

moon is full in the node, it is called a central eclipse.

James. I suppose the duration of the eclipse lasts all the time that the moon is passing through the shadow.

Tutor. It does: and you observe that the shadow is considerably wider than the moon's diameter, and therefore an eclipse of the moon lasts sometimes three or four hours. The shadow also you perceive is of a conical shape, and consequently, as the moon's orbit is an ellipse and not a circle, the moon will, at different times, be eclipsed when she is at different distances from the earth.

Charles. And, according as the moon is nearer to, or farther from the earth, the eclipse will be of a

greater or less duration: for the shadow being conical becomes less and less, as the distance from the body by which it is cast is greater.

Tutor. It is by knowing exactly at what distance the moon is from the earth, and of course the width of the earth's shadow at that distance, that all eclipses are calculated with the greatest accuracy, for many years before they happen. Now it is found, that, in all eclipses, the shadow of the earth is conical, which is a demonstration, that the body by which it is projected is of a spherical form, for no other sort of figure would, in *all positions*, cast a conical shadow. This is mentioned as another proof, that the earth is a spherical body.

James. It seems to me to

prove another thing, *viz.* that the sun must be a larger body than the earth.

Tutor. Your conclusion is just, for if the two bodies were equal to one another (Plate III, Fig. 13) the shadow would be cylindrical: and if the earth were the larger body (Plate III, Fig. 14) its shadow would be of the figure of a cone, which had lost its vertex, and the farther it were extended the larger it would become. In either case the shadow would run out to an infinite space, and accordingly must sometimes involve in it the other planets, and eclipse them, which is contrary to fact. Therefore, since the earth is neither larger than, nor equal to the sun, it must be the lesser body. We will now proceed to the eclipses of the sun.

Charles. How are these occasioned?

Tutor. An eclipse of the sun happens when the moon M, passing between the sun S and the earth T (Plate III, Fig. 15), intercepts the sun's light from coming to the earth.

James. The sun then can be eclipsed only at the new moon?

Tutor. Certainly; for it is only when the moon is in *conjunction* that it can pass directly between the sun and earth.

Charles. Is it only when the moon at her conjunction is near one of its nodes, that there can be an eclipse of the sun?

Tutor. An eclipse of the sun depends upon this circumstance: for unless the moon is in, or near one of

its nodes, she cannot appear in the same plane with the sun, or seem to pass over his disk. In every other part of the orbit, she will appear above or below the sun. If the moon be *in* one of the nodes, she will, in most cases, cover the whole disk of the sun, and produce a *total* eclipse; if she be any where within about 16 degrees of a node, a *partial* eclipse will be produced.

The sun's diameter is supposed to be divided into 12 equal parts, called *digits*, and in every partial eclipse, as many of these parts of the sun's diameter as the moon covers, so many digits are said to be eclipsed.

James. I have heard of *annular* eclipses, what are they, Sir?

Tutor. When a ring of light appears round the edge of the moon

during an eclipse of the sun, it is said to be annular, from the Latin word *annulus* a *ring*: these kind of eclipses are occasioned by the moon being at her greatest distance from the earth at the time of an eclipse; because, in that situation, the vertex, or tip of the cone of the moon's shadow, does not reach the surface of the earth.

Charles. How long can an eclipse of the sun last?

Tutor. A total eclipse of the sun is a very curious and uncommon spectacle; and total darkness cannot last more than three or four minutes. Of one that was observed in Portugal, 160 years ago, it is said that the darkness was greater than that of the night;—that stars of the first magnitude made their ap-

pearance; and that the birds were so terrified that they fell to the ground.

James. Was this visible only at Portugal?

Tutor. It must have been seen at other places though we have no account of it. The moon, however, being a body much smaller than the earth, and having also a conical shadow, can with that shadow only cover a small part of the earth; whereas an eclipse of the moon may be seen by all those that are on that hemisphere which is turned towards it. (See Plate III, Fig. 15 and 12.)

You will also observe, that an eclipse of the sun may be *total* to the inhabitants near the middle of the earth's disk, and *annular* to those in places near the edges of

the disk; for in the former case the moon's shadow will reach the earth, and in the latter, on account of the earth's sphericity, it will not.

Charles. Have not eclipses been esteemed as omens presaging some direful calamity?

Tutor. Till the causes of these appearances were discovered, they were generally beheld with terror by the inhabitants of the world, which fact is beautifully alluded to by Milton in the 1st book of Paradise Lost, line 594:—

————————As when the sun, new risen,
Looks through the horizontal misty air
Shorn of his beams, or from behind the moon,
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs.

CONVERSATION XVI.

Of the Tides.

TUTOR. We will proceed to the consideration of the *Tides*, or the flowing and ebbing of the ocean.

James. Is this subject connected with astronomy?

Tutor. It is, inasmuch as the tides are occasioned by the attraction of the sun and moon upon the waters, but more particularly by that of the latter. You will readily conceive that the tides are dependent upon some known and determinate laws, because, if you turn to the Ephe-

meris, or indeed to almost any almanac, you will see that the exact time of high water at London Bridge for every day in the year is set down.

Charles. I have frequently wondered how this could be known with such a degree of accuracy: indeed there is not a waterman, that plies at the stairs, but can readily tell when it will be high water.

Tutor. The generality of the watermen are probably as ignorant as yourself of the cause by which the waters flow and ebb, but by experience they know that the time of high water differs on each day about three quarters of an hour, or a little more or less, and therefore, if it be high water to-day at six o'clock, they will, at a guess, tell you, that

to morrow the tide will not be up till a quarter before seven.

James. Will you explain the causes?

Tutor. I will endeavour to do this in an easy and concise manner, without fatiguing your memory with a great variety of particulars:—

> The ebbs of tides, and their mysterious flow,
> We, as art's elements, shall understand.
>
> DRYDEN.

You must bear in your mind then, that the tides are occasioned by the attractions of the sun and moon upon the waters of the earth: perhaps a figure may be of some assistance to you. Let A *p* L *n* (Plate III, Fig. 16) be supposed the earth, C its centre; let the dotted circle represent a mass of water co-

vering the earth: let M be the moon in its orbit, and S the sun.

Since the force of gravity or attraction diminishes as the squares of the distances increase*, the waters on the side A are more attracted by the moon M, than the central parts at C; and the central parts are more attracted than the waters at L; consequently the waters at L will recede from the centre; therefore, while the moon is in the situation M, the waters will rise towards *a* and *b* on the opposite sides of the earth.

Charles. You mean that the waters will rise at *a* by the immediate attraction of the moon M, and will rise at *b* by the centre C receding and leaving them more elevated there.

* See Vol. I, p. 54.

Tutor. That is the explanation. It is evident that the quantity of water being the same, a rise cannot take place at *a* and *b*, without the parts at P and N being at the same time depressed.

James. In this situation the water may be considered as partaking of an oval form.

Tutor. If the earth and moon were without motion, and the earth covered all over with water, the attraction of the moon would raise it up in a heap in that part of the ocean to which the moon is vertical, and there it would always continue; but, by the rotation of the earth on its axis, each part of its surface to which the moon is vertical is presented twice a day to the action of the moon, and thus are produced two floods and two ebbs: —

> Alternate tides in sacred order run.
>
> BLACKMORE.

Charles. How twice a day?

Tutor. In the position of the earth and moon as it is in our figure, the waters are raised at A by the direct attraction of the moon, and a tide is accordingly produced: but when, by the earth's rotation, A comes, 12 hours afterwards, into the position L, another tide is occasioned by the receding of the waters there from the centre.

James. You have told us, that the tides are produced in those parts of the earth to which the moon is vertical, but this effect is not confined to those parts?

Tutor. It is not, but there the attraction of the moon has the great-

est effect: in all other parts her force is weaker, because it acts in a more oblique direction.

Charles. Are there two tides in every 24 hours?

Tutor. If the moon were stationary this would be the case; but because that body is also proceeding every day about 13 degrees from west to east in her orbit, the earth must make more than one revolution on its axis before the same meridian is in conjunction with the moon, and hence two tides take place in about 24 hours and 50 minutes.

James. But I remember, when we were at the sea, that the tides rose higher at some seasons than at others: how do you account for this?

Tutor. The moon goes round the earth in an elliptic orbit, and

therefore she approaches nearer to the earth in some parts of her orbit than in others. When she is nearest, the attraction is the strongest, and consequently it raises the tides most; and when she is farthest from the earth, her attraction is the least, and the tides the lowest.

James. Do they rise to different heights in different places?

Tutor. They do: in the Black Sea and the Mediterranean the tides are scarcely perceptible. At the mouth of the Indus the water rises and falls full 30 feet. The tides are remarkably high on the coast of Malay, in the Straits of Sunda, in the Red Sea, along the coasts of China, Japan, &c. In general, the tides rise highest and strongest in those places that are narrowest.

Charles. You said the sun's attraction occasioned tides as well as that of the moon.

Tutor. It does; but, owing to the immense distance of the sun from the earth, it produces but a small effect, in comparison of the moon's attraction. Sir Isaac Newton computed, that the force of the moon raised the waters in the great ocean 10 feet, whereas that of the sun raised it only 2 feet. When both the attraction of the sun and moon act in the same direction, that is, at new and full moon, the combined forces of both raise the tide 12 feet. But when the moon is in her quarters, the attraction of one of these bodies raises the water, while that of the other depresses it; and therefore the smaller force of the sun

must be subtracted from that of the moon, consequently the tides will be no more than 8 feet. The highest tides are called spring tides, and the lowest are denominated neap tides.

James. I understand, that, in the former case, the height to which the tides are raised must be calculated by *adding* together the attractions of the sun and moon; and in the latter, it must be estimated by the *difference* of these attractions.

Tutor. You are right. When the sun and moon are both vertical to the equator of the earth, and the moon at her least distance from the earth, then the tides are highest.

Charles. Do the highest tides happen at the equinoxes?

Tutor. Strictly speaking, these

tides do not happen till some little time after, because in this, as in other cases, the actions do not produce the greatest effect when they are at the strongest, but some time afterwards: thus the hottest part of the day is not when the sun is on the meridian, but between two and four o'clock in the afternoon. Another circumstance must be taken into consideration: the sun being nearer to the earth in winter than in summer, it is of course nearer to it in February and October, than in March and September; and therefore, all these things being put together, it will be found that the greatest tides happen a little before the vernal, and some time after the autumnal equinoxes.

CONVERSATION XVII.

Of the Harvest Moon.

TUTOR. From what we said yesterday, you will easily understand the reason why the moon rises about three quarters of an hour later every day than on the one preceding.

Charles. It is owing to the daily progress which the moon is making in her orbit, on which account any meridian on the earth must make more than one complete rotation on its axis, before it comes again into the same situation with respect to

the moon that it had before. And you told us that this occasioned a difference of about 50 minutes.

Tutor. At the equator this is generally the difference of time between the rising of the moon on one day and the preceding. But in places of considerable latitude, as that in which we live, there is a remarkable difference about the time of harvest, when at the season of full moon she rises for several nights together only about 20 minutes later on the one day than on that immediately preceding. By thus succeeding the sun before the twilight is ended, the moon prolongs the light to the great benefit of those who are engaged in gathering in the fruits of the earth; and hence the full moon at this season is called the harvest moon. It

is believed that this was observed by persons engaged in agriculture, at a much earlier period than it was noticed by astronomers; the former ascribed it to the goodness of the Deity, not doubting but that he had ordered it so on purpose for their advantage.

James. But the people at the equator do not enjoy this benefit.

Tutor. Nor is it necessary that they should, for in those parts of the earth the seasons vary but little, and the weather changes but seldom, and at stated times; to them, then, moonlight is not wanting for gathering the fruits of the earth.

Charles. Can you explain how it happens, that the moon at this season of the year rises one day after another with so small a difference of time?

Tutor. With the assistance of a globe I could at once clear the matter up. But I will endeavour to give you a general idea of the subject without that instrument. That the moon loses more time in her risings when she is in one part of her orbit, and less in another, is occasioned by the moon's orbit lying sometimes more oblique to the horizon than at others.

James. But the moon's path is not marked on the globe.

Tutor. It is not; you may, however, consider it, without much error, as coinciding with the ecliptic. And in the latitude of London, as much of the ecliptic rises about *Pisces* and *Aries* in two hours as the moon goes through in six days; therefore, while the moon is in these signs, she differs

but two hours in rising for six days together, that is, one day with another, about 20 minutes later every day than on the preceding.

There is a time, well known to husbandmen,
In which the moon for many nights, in aid
Of their autumnal labours, cheers the dusk
With her full lustre, soon as Phœbus hides
Beneath th' horizon his propitious ray:
For as the angle of the line, which bounds
The moon's career from the equator, flows
Greater or less, the orb of Cynthia shines
With less or more of difference in rise;
In *Aries* least this angle: thence the moon
Rises with smallest variance of times
When in this sign she dwells, and most protracts
Her sojourning in our enlighten'd skies.

LOFFT.

Charles. Is the moon in those signs at the time of harvest?

Tutor. In August and September you know that the sun appears in

Virgo and Libra, and, of course, when the moon is *full*, she must be in the opposite signs, *viz*. *Pisces* and *Aries*.

James. Are there then two full moons that afford us this advantage?

Tutor. There are; the one when the sun is in Virgo, which is called the *harvest* moon; the other when the sun is in Libra, and which, being less advantageous, is called the *hunter's* moon. You ought to be told, that when the moon is in Virgo and Libra, then she rises with the greatest difference of time, *viz*. an hour and a quarter later every day than the former.

Charles. Will you explain, Sir, how it is that the people at the equator have no harvest moon?

Tutor. At the equator, the north and south poles lie in the horizon, and

therefore the ecliptic makes the same angle southward with the horizon when Aries rises, as it does northward when Libra rises; but, as the harvest moon depends upon the different angles at which different parts of the ecliptic rise, it is evident there can be no harvest moon at the equator.

The farther any place is from the equator, if it be not beyond the polar circles, the angle, which the ecliptic makes with the horizon, when Pisces and Aries rise, gradually diminishes; and, therefore, when the moon is in these signs, she rises with a nearly proportionable difference later every day than on the former, and this is more remarkable about the time of full moon.

James. Why have you excepted

the space on the globe beyond the polar circles?

Tutor. At the polar circles, when the sun touches the summer tropic, he continues 24 hours above the horizon, and 24 hours below it when he touches the winter tropic. For the same reason, the full moon neither rises in the summer, when she is not wanted, nor sets in the winter, when her presence is so necessary. These are the only two full moons which happen when the sun is in the tropics, for all the others rise and set. In summer the full moons are low, and their stay above the horizon short; in winter they are high, and stay long above the horizon. A wonderful display this of the divine wisdom and goodness, in apportioning the quantity of light, suitable to the various

necessities of the inhabitants of the earth, according to their different situations.

Charles. At the poles, the matter is, I suppose, still different.

Tutor. There one half of the ecliptic never sets, and the other half never rises; consequently the sun continues one half year above the horizon, and the other half below it. The full moon, being always opposite to the sun, can never be seen by the inhabitants of the poles, while the sun is above the horizon. But all the time that the sun is below the horizon, the full moons never set. Consequently, to them the full moon is never visible in their summer; and in their winter they have her always before and after the full, shining for 14 of our days and nights without

intermission. And when the sun is depressed the lowest under the horizon, then the moon ascends with her highest altitude.

James. This indeed exhibits in a high degree the attention of Providence to all his creatures. But if I understand you, the inhabitants of the poles have in their winter a fortnight's light and darkness by turns?

Tutor. This would be the case, for the whole six months that the sun is below the horizon, if there were no refraction*, and no substitute for the light of the moon. But, by the atmosphere's refracting the sun's rays, he becomes visible a fortnight sooner, and continues a fort-

* The subject of refraction will be very particularly explained when we come to Optics.

night longer in sight, than he would otherwise do, were there no such property belonging to the atmosphere. And in those parts of the winter, when it would be absolutely dark in the absence of the moon, the brilliancy of the *Aurora Borealis* is probably so great as to afford a very comfortable degree of light. Mr. Hearne, in his travels near the polar circle, has this remark in his journal: "December 24. The days were so short, that the sun only took a circuit of a few points of the compass above the horizon. and did not, at its greatest altitude, rise half way up the trees. The brilliancy of the Aurora Borealis, however, and of the stars, even without the assistance of the moon, made amends for this deficiency, for it was frequently so

light all night, that I could see to read a small print."

These advantages are poetically described by our Thomson:—

By dancing meteors then, that ceaseless shake
A waving blaze refracted o'er the heavens,
And vivid moons, and stars that keener play
With double lustre from the glossy waste,
Ev'n in the depth of polar night, they find
A wondrous day; enough to light the chase,
Or guide their daring steps to Finland fairs.

WINTER, l. 859.

CONVERSATION XVIII.

Of Mercury.

TUTOR. Having fully described the earth and the moon, the former a primary planet, and the latter its attendant satellite, or secondary planet, we shall next consider the other planets in their order, with which, however, we are less interested.

MERCURY, you recollect, is the planet nearest the sun; and Venus is the second in order. These are called inferior planets.

Charles. Why are they thus denominated?

Tutor. Because they both revolve in orbits which are included *within* that of the earth; thus (Plate 1, Fig. 2) Mercury makes his annual journey round the sun in the orbit *a*, Venus in *b*, and the earth, farther from that luminary than either of them, makes its circuit in *t*.

James. How is this known?

Tutor. By observation: for, by attentively watching the progress of these bodies, it is found that they are continually changing their places among the fixed stars, and that they are never seen in opposition to the sun; that is, they are never seen in the western side of the heavens in the morning when he appears in the east, nor in the eastern part of the heavens in the evening when the sun appears in the west.

Charles. Then they may be considered as attendants upon the sun?

Tutor. They may: Mercury is never seen from the earth at a greater distance from the sun than about 28 degrees, or about as far as the moon appears to be from the sun on the second day after its change; hence it is that we so seldom see him; and when we do, it is for so short a time, and always in twilight, that sufficient observations have not been made to ascertain whether he has a diurnal motion on his axis.

James. Would you then conclude that he has such a motion?

Tutor. I think we ought; because it is known to exist in all those planets upon which observations of sufficient extent have been made, and therefore we may surely infer, with

out much chance of error, that it belongs also to Mercury and the Herschel; the former, from its vicinity to the sun, and the latter, from its great distance from that body, having at present eluded the investigation of the most indefatigable astronomers.

Charles. At what distance is Mercury from the sun?

Tutor. He revolves round that body at about 37 millions of miles distance, in 88 days nearly; and therefore you can now tell me how many miles he travels in an hour.

James. I can; for supposing his orbit circular, I must multiply the 37 millions by 6 *; which will give 222 millions of miles for the length of his orbit; this I shall divide by

* See page 80.

88, the number of days he takes in performing his journey, and the quotient resulting from this must be divided by 24, for the number of hours in a day; and by these operations I find that Mercury travels at the rate of more than 105,000 miles in an hour.

Charles. How large is Mercury?

Tutor. He is the smallest of all the planets, his diameter is something more than 3200 miles in length.

James. His situation being so much nearer to the sun than ours, he must enjoy a considerably greater share of its heat and light.

Tutor. So much so, as would indeed infallibly burn every thing belonging to the earth to atoms, were she similarly situated. The heat of

the sun, at Mercury, must be 7 times greater than our summer heat:—

——————Mercury the first,
Near bordering on the day, with speedy wheel
Flies swiftest on, inflaming where he comes,
With *seven-fold* splendour, all the azure road.

MALLET'S EXCURSION.

Charles. And do you imagine that, thus circumstanced, this planet can be inhabited?

Tutor. Not by such beings as we are: you and I could not long exist at the bottom of the sea; yet the sea is the habitation of millions of living creatures; why then may there not be inhabitants in Mercury, fitted for the enjoyment of the situation which that planet is calculated to afford? If there be not, we must be at a loss to know why such a body was formed; certainly it could not

be intended for our benefit, for it is rarely even seen by us:—

Ask for what end the heav'nly bodies shine?
Earth for whose use? Pride answers, " 'Tis
for mine:
——————— suns to light me rise,
My footstool earth, my canopy the skies."

POPE.

But do these worlds display their beams, or
guide
Their orbs, to serve thy use, to please thy pride?
Thyself but dust, thy stature but a span,
A moment thy duration: foolish man!
As well may the minutest emmet say,
That Caucasus was rais'd to pave his way:
The snail, that Lebanon's extended wood
Was destin'd only for his walk and food:
The vilest cockle, gaping on the coast
That rounds the ample seas, as well may boast,
The craggy rock projects above the sky,
That he in safety at its foot may lie;
And the whole ocean's confluent waters swell
Only to quench his thirst, or move and blanch
his shell.

PRIOR.

CONVERSATION XIX.

Of Venus.

TUTOR. We now proceed to Venus, the second planet in the order of the solar system, but by far the most beautiful of them all:—

Fairest of stars, last in the train of night,
If better thou belong not to the dawn,
Sure pledge of day, that crown'st the smiling
morn
With thy bright circlet, praise him in thy
sphere,
While day arises, that sweet hour of prime.
MILTON.

James. How far is Venus from the sun?

Tutor. That planet is 68 millions of miles from the sun, and she finishes her journey in $224\frac{1}{4}$ days, consequently she must travel at the rate of 75,000 miles in an hour.

Charles. Venus is larger than Mercury, I dare say?

Tutor. Yes, she is nearly as large as the earth, which she resembles also in other respects, her diameter being about 7700 miles in length, and she has a rotation about her axis in 23 hours and 20 minutes. The quantity of light and heat, which she enjoys from the sun, must be double that which is experienced by the inhabitants of this globe.

James. Is there also a difference in her seasons, as there is here?

Tutor. Yes, in a much more considerable degree. The axis of Venus

inclines about 75 degrees, but that of the earth inclines only $23\frac{1}{2}$ degrees; and as the variety of the seasons in every planet depends on the degree of the inclination of its axis, it is evident that the seasons must vary more with Venus than with us.

Charles. Venus appears to us larger sometimes than at others.

Tutor. She does: and the great variations of the apparent diameter of Venus demonstrate, that her distance from the earth is exceedingly variable. It is largest when the planet passes over the disk of the sun; that is, as we shall soon see, when there is a transit. Suppose S (Plate III, Fig. 17) to be the sun, T the earth in her orbit, and *a*, *b*, *c*, *d*, *e*, *f*, Venus in hers: now it is evident that when Venus is at *a*, between

the sun and earth, she would, if visible, appear much larger than when she is at *d*, in opposition.

James. That is because she is so much nearer in the former case than in the latter, being in the situation *a* but 27 millions of miles from the earth T, but at *d* she is 163 millions of miles off.

Tutor. Now, as Venus passes from *a*, through *b*, *c*, to *d*, she may be observed, by means of a good telescope, to have all the same phases as the moon has in passing from new to full; therefore when she is at *d* she is full, and is seen among the fixed stars in the beginning of Cancer: during her journey from *d* to *e*, she proceeds with a *direct* motion in her orbit, and at *e* she is seen in Leo, and will appear to an inhabitant of the earth, for a few

days, to be *stationary*, not seeming to change her place among the fixed stars, for she is coming toward the earth in a direct line: but passing from *e* to *f*, though still with a direct motion, yet, to a spectator at T, her course will seem to be back again, or *retrograde*, for she will seem to have gone back from *z* to *y*; her path will appear retrograde till she gets to *c*, when she will again appear *stationary*, and afterwards, from *c* to *d* and from *d* to *e*, it will be *direct* among the fixed stars.

Charles. When is Venus an evening, and when a morning star?

Tutor. She is an evening star all the while she appears *east* of the sun, and a morning star while she is seen *west* of him:—

Next Venus to the *westward* of the sun,
Full orb'd her face, a golden plain of light
Circles her larger round. Fair *morning* star
That leads on dawning day to yonder world
The *seat of Man*.

MALLET'S EXCURSION.

When she is at *a* she will be invisible, her dark side being towards us, unless she be exactly in the node, in which case she will pass over the sun's face like a little black spot.

James. Is that called the transit of Venus?

Tutor. It is; and it happens twice only in about 120 years. By this phenomenon astronomers have been enabled to ascertain with great accuracy the distance of the earth from the sun; and, having obtained this, the distances of the other planets are easily found. By the two transits, which happened in 1761 and 1769,

it was clearly demonstrated, that the mean distance of the earth from the sun was between 95 and 96 millions of miles.

Charles. How do you find the distances of the other planets from the sun, by knowing that of the earth? *

Tutor. I will endeavour to make this plain to you. Kepler, a great astronomer, discovered that all the planets are subject to one general law, which is, that the *squares of their periodical times are proportional to the cubes of their distances from the sun.*

* The remainder of this Conversation may be omitted by those young persons who are not ready in arithmetical operations. The author, however, knows, from experience, that children may, at a very early age, be brought to understand these higher parts of arithmetic.

James. What do you mean by the *periodical times?*

Tutor. I mean the times which the planets take in revolving round the sun; thus the periodical time of the earth is $365\frac{1}{4}$ days; that of Venus $224\frac{1}{4}$ days; that of Mercury 88 days.

Charles. How then would you find the distance of Mercury from the sun?

Tutor. By the rule of three: I would say as the square of 365 days (the time which the earth takes in revolving about the sun) is to the square of 88 days (the time in which Mercury revolves about the sun), so is the cube of 95 millions (the distance in miles of the earth from the sun) to a fourth number.

James. And is that fourth num-

ber the distance in miles of Mercury from the sun?

Tutor. No: you must extract the cube root of that number, and then you will have about 38 millions of miles for the answer, which is the distance at which Mercury revolves about the sun.

Charles. Does Venus turn round on her axis?

Tutor. From the movement of certain spots upon the surface of the planet, it has been concluded, that she revolves about her axis once in 24 hours. But this is by no means completely ascertained.

CONVERSATION XX.

Of Mars.

TUTOR. Next to Venus is the earth and her satellite the moon; but of these sufficient notice has already been taken, and therefore we shall pass on to the planet Mars, which is known in the heavens by a dusky red appearance. Mars, together with Jupiter, Saturn, and the Herschel, are called superior planets, because the orbit of the earth is enclosed by their orbits.

Charles. At what distance is Mars from the sun?

Tutor. About 144 millions of miles; the length of his year is equal to 687 of our days, and therefore he travels at the rate of more than 53 thousand miles in an hour: his diurnal rotation on his axis is performed in 24 hours and 39 minutes, which makes his figure that of an oblate spheroid.

James. How is the diurnal motion of this planet discovered?

Tutor. By means of a very large spot which is seen distinctly on his face, when he is in that part of his orbit which is opposite to the sun and earth.

Charles. Is Mars as large as the earth?

Tutor. No: his diameter is only 4189 miles in length, which is but little more than half the length of

the earth's diameter. And owing to his distance from the sun he will not enjoy one half of the light and heat which we enjoy.

James. And yet, I believe, he has not the benefit of a moon?

Tutor. No moon has ever been discovered belonging either to Mercury, Venus, or Mars.

Charles. Do the superior planets exhibit similar appearances of direct and retrogade motion to those of the inferior planets?

Tutor. They do: suppose s (Plate IV, Fig. 18) the sun; *a, b, d, f, g, h*, the earth in different parts of its orbit, and *m* Mars in his orbit. When the earth is at *a*, Mars will appear among the fixed stars at *x*: when by its annual motion the earth has arrived at *b, d*, and *f*, respectively,

the planet Mars will appear in the heavens at *y*, *z*, and *w*: when the earth has advanced to *g*, Mars will appear stationary at *o*: to the earth, in its journey from *g* to *h*, the planet will seem to go backwards or retrograde in the heavens from *o* to *z*, and this retrograde motion will be apparent till the earth has arrived at *a*, when the planet will again appear stationary.

James. I perceive that Mars is retrograde when in *opposition*, and the same is, I suppose, applicable to the other superior planets; but the retrograde motion of Mercury and Venus is when those planets are in *conjunction*.

Tutor. You are right: and you see the reason, I dare say, why the superior planets may be in the west

in the morning when the sun rises in the east, and the reverse.

Charles. For when the earth is at *d*, Mars may be at *n*, in which case the earth is between the sun and the planet: I observe also that the planet Mars, and consequently the other superior planets, are much nearer the earth at one time than at others.

Tutor. The difference with respect to Mars is no less than 190 millions of miles, the whole length of the orbit of the earth. This will be a proper time to explain what is meant by the *heliocentric* longitude of the planets referred to in the Ephemeris.

James. Yes, I remember you promised to explain this when you came to speak of the planets; I do not know the meaning of the word heliocentric.

Tutor. It is a term used to express the place of any heavenly body, as seen from the sun; whereas the *geocentric* place of a planet is the position which it has when seen from the earth.

Charles. Will you show us by a figure in what this difference consists?

Tutor. I will: let s (Plate IV, Fig. 19) represent the place of the sun, *b* Venus in its orbit, *a* the earth in hers, and *c* Mars in his orbit, and the outermost circle will represent the sphere of fixed stars. Now, to a spectator on the earth *a*, Venus will appear among the fixed stars in the beginning of Scorpio, but, as viewed from the sun, she will be seen beyond the middle of Leo. Therefore the *geocentric* longitude of Venus will be in Scorpio, but her *heliocentric*

longitude will be in Leo. Again, to a spectator at *a* the planet Mars at *c* will appear among the fixed stars towards the end of the sign of Pisces; but, as viewed from the sun, he will be seen at the beginning of the sign Aries; consequently the *geocentric* longitude of Mars is in Pisces; but his *heliocentric* longitude is in Aries.

CONVERSATION XXI.

Of Jupiter.

TUTOR. We now come to Jupiter, the largest of all the planets, which is easily known by his peculiar magnitude and brilliancy.

Charles. Is Jupiter larger than Venus?

Tutor. Though he does not appear so large, yet the magnitude of Venus bears but a very small proportion to that of Jupiter, whose diameter is 90,000 miles in length; consequently his bulk will exceed

the bulk of Venus 1500 times: his distance from the sun is estimated at more than 490 millions of miles.

James. Then he is *five* times farther from the sun than the earth; and, consequently, as light and heat diminish in the same proportion as the squares of the distances from the illuminating body increase, the inhabitants of Jupiter enjoy but a twenty-fifth part of the light and heat of the sun that we enjoy.

Tutor. Another thing remarkable in this planet is, that it revolves on its axis, which is perpendicular to its orbit, in 10 hours, and, in consequence of this swift diurnal rotation, his equatorial diameter is 6000 miles greater than his polar diameter.

Charles. Since then a variety in the seasons of a planet depends upon the inclination of the axis to its orbit, and since the axis of Jupiter has no inclination, there can be no difference in his seasons, nor any in the length of his days and nights.

Tutor. You are right; his days and nights are always five hours each in length; and at his equator, and its neighbourhood, there is perpetual summer; and an everlasting winter in the polar regions.

James. What is the length of his years?

Tutor. It is equal to nearly 12 of ours, for he takes 12 years, 314 days, and 10 hours, to make a revolution round the sun, consequently

he travels at the rate of more than 28,000 miles in an hour.

This noble planet is accompanied with four satellites, which revolve about him at different distances, and in different periodical times; the *first* in about 1 day and 18 hours: the *second* in 3 days 13 hours: the *third* in 7 days 3 hours: and the *fourth* in 16 days and 16 hours.

Beyond the sphere of *Mars*, in distant skies,
Revolves the mighty magnitude of *Jove*
With kingly state, the rival of the sun.
About him round *four planetary moons*,
On earth with wonder all night long beheld,
Moon above moon, his fair attendants dance.

MALLET'S EXCURSION.

Charles. And are these satellites, like our moon, subject to be eclipsed?

Tutor. They are; and their

eclipses are of considerable importance to astronomers, in ascertaining with accuracy the longitude of different places on the earth.

By means of the eclipses of Jupiter's satellites, a method has been also obtained of demonstrating that the motion of light is *progressive* and not *instantaneous*, as was once supposed. Hence it is found, that the velocity of light is nearly 11,000 times greater than the velocity of the earth in its orbit, and more than a million of times greater than that of a ball issuing from a cannon. This discovery is alluded to by the last mentioned poet: speaking of an observer of the eclipses and Jupiter's satellites, he says,

By these observ'd, the *rapid progress finds*
Of *light* itself; how swift the headlong ray

Shoots from the sun's height through unbounded space,
At once enlight'ning air, and earth, and heaven.

Rays of light come from the sun to the earth in 8 minutes, that is, at the rate of about 12 millions of miles in a minute.

James. Who discovered these satellites?

Tutor. They were first seen by Galileo in 1610. He took them for telescopic stars, but farther observations convinced him and others, that they were planetary bodies.

The relative situation of these small bodies changes at every instant. They are sometimes seen to pass over the face of the planet, and project a shadow in the form of a black spot, which describes a line across it.

CONVERSATION XXII.

Of Saturn.

TUTOR. We are now arrived at Saturn in our descriptions, which, till within these twenty years, was esteemed the most remote planet of the solar system.

Charles. How is he distinguished in the heavens?

Tutor. He shines with a pale dead light, very unlike the brilliant Jupiter, yet his magnitude seems to vie with that of Jupiter himself. The diameter of Saturn is nearly 80

thousand miles in length: his distance from the sun is more than 900 millions of miles, and he performs his journey round that luminary in a little less than 30 of our years, consequently he must travel at a rate not much short of 21,000 miles an hour.

James. His great distance from the sun must render an abode on Saturn extremely cold and dark too, in comparison of what we experience here.

Tutor. His distance from the sun being between 9 and 10 times greater than that of the earth, he enjoys about 90 times less light and heat; it has nevertheless been calculated, that the light of the sun at Saturn is 500 times greater than that which we enjoy from our *full moon.*

Charles. The day-light at Saturn, then, cannot be very contemptible: I should hardly have thought, that the light of the sun here was 500 times greater than that experienced from a full moon.

Tutor. So much greater is our meridian light than this, that during the sun's absence behind a cloud, when the light is much less strong than when we behold him in all his glorious splendour, it is reckoned that our day-light is 90,000 times greater than the light of the moon at its full.

James. But Saturn has several moons, I believe?

Tutor. He is attended by *seven* satellites, or moons, whose periodical times d.ffer very much; the one nearest to him performs a revolution

round the primary planet in 22 hours and a half; and that which is most remote takes 79 days and 7 hours for his monthly journey: this last satellite is known to turn on its axis, and in its rotation is subject to the same law which our moon obeys, that is, it revolves on its axis in the same time in which it revolves about the planet.

Besides the seven moons, Saturn is encompassed with two broad rings, which are probably of considerable importance in reflecting the light of the sun to that planet; the breadth of the inner ring is 20,000 miles, that of the outer ring is 7200 miles, and the vacant space between the two rings is 2839 miles. These rings give Saturn a very different appearance to any of the other planets. Plate IV, Fig. 20, is a repre-

sentation of Saturn as seen through a good telescope. On the supposition that Saturn was the most remote planet of our system, he is thus described by Mallet, in his Excursion:—

Last, outmost Saturn walks his frontier round,
The boundary of worlds, with his pale moons,
Faint glimm'ring through the gloom which night has thrown
Deep-dyed and dead o'er this chill globe forlorn:
An endless desert, where extreme of cold
Eternal sits, as in his native seat,
On wintry hills of never-thawing ice.
Such *Saturn's* earth; and even here the sight,
Amid these doleful scenes, new matter finds
Of wonder and delight! a mighty *ring!*

James. Is it known of what nature the ring is?

Tutor. Dr. Herschel thinks it no less solid than that of the planet itself, and he has found that it casts a

strong shadow upon the planet. The light of the ring is brighter than that of the planet; for the ring appears sufficiently bright for observation, at times when the telescope scarcely affords light enough to give a fair view of Saturn.

Charles. Is it known whether Saturn turns on its axis?

Tutor. According to Dr. Herschel it has a rotation about its axis in 12 hours $13\frac{1}{4}$ minutes: this he computed from the equatorial diameter being longer than the polar diameter in the proportion of 11 to 10. Dr. Herschel has also discovered, that the ring, just mentioned, revolves about the planet in 10 hours and a half.

CONVERSATION XXIII.

Of the Herschel Planet.

TUTOR. We have but one other planet to describe, that is the Herschel.

James. Was it discovered by Dr. Herschel?

Tutor. It was, on the 13th of March, 1781, and therefore by astronomers, in general, it is denominated the Herschel planet: though by the doctor himself it was named the Georgium Sidus, or Georgian star, in honour of his present majesty George the Third, who has for many years been a liberal patron to this

great and most indefatigable astronomer.

Charles. I do not think that I have ever seen this planet.

Tutor. Its apparent diameter is too small to be discerned readily by the naked eye, but it may be easily discovered in a clear night, when it is above the horizon, by means of a good telescope, its situation being previously known from the Ephemeris.

James. Is it owing to the smallness of this planet,* or to its great distance from the sun, that we cannot see it with the naked eye?

Tutor. Both these causes are combined: in comparison of Jupiter and Saturn it is small, his diameter being less than 35 thousand miles in length; and his distance from the sun is estimated at more than 1800

millions of miles from that luminary, around which, however, he performs his journey in 82 of our years, consequently he must travel at the rate of 16,000 miles an hour.

Charles. But, if this planet has been discovered only 22 years, how is it known that it will complete its revolution in 82 years.

Tutor. By a long series of observations it was found to move with such a velocity as would carry it round the heavens in that period. Moreover, when it was first discovered, it was in Gemini, and, in August 1803, it had advanced to the 11° of Libra, more than a fourth part of its journey; and now, in June 1809, it is in the 8th of Scorpio.

James. How many moons has the Herschel?

Tutor. He is attended by six satellites, or moons, of which, the one nearest to the planet performs his revolution round the primary in 5 days and 23 hours, but that which is the most remote from him takes 107 days and 16 hours for his journey.

Charles. Is there any idea formed as to the light and heat enjoyed by this planet?

Tutor. His distance from the sun is 19 times greater than that of the earth, consequently, since the square of 19 is 361, the light and heat experienced by the inhabitants of that planet must be 361 times less than *we* derive from the rays of the sun.

The proportion of light enjoyed by the Herschel has been estimated at about equal to the effect of 249 of our full moons.

CONVERSATION XXIV.

Of Comets.

TUTOR. Besides the seven primary planets, and the eighteen secondary ones or satellites, which we have been describing, there are other bodies belonging to the solar system, called comets, to which Thomson in his Summer beautifully alludes:—

——————— Amid the radiant orbs
That more than deck, that animate the sky,
The life-infusing suns of other worlds,
Lo! from the dread immensity of space
Returning with accelerated course
The rushing *comet* to the sun descends,
And as he sinks below the shading earth,
With awful train projected o'er the heavens,
The guilty nations tremble.

SUMMER, line 1702.

Charles. Do comets resemble the planets in any respects?

Tutor. Like them they are supposed to revolve about the sun in elliptical orbits, and to describe equal areas in equal times; but they do not appear to be adapted for the habitation of animated beings, owing to the great degrees of heat and cold to which, in their course, they must be subjected.

The comet seen by Sir Isaac Newton in the year 1680, was observed to approach so near the sun, that its heat was estimated by that great man, to be 2000 times greater than that of red-hot iron.

James. It must have been a very solid body to have endured such a heat without being entirely dissipated.

Tutor. So indeed it should seem: and a body thus heated must retain

its heat a long time: for a red-hot globe of iron, of a single inch in diameter, exposed to the open air, will scarcely lose all its heat in an hour; and it is said, that a globe of red-hot iron, as large as our earth, would scarcely cool in 50,000 years. —See Enfield's Institutes of Natural Philosophy, page 296, second edit.

Charles. Are the periodical times of the comets known?

Tutor. Not with any degree of certainty: it was supposed that the periods of three of them had been distinctly ascertained. The *first* of these appeared in the years 1531, 1607, and 1682, and it was expected to return every 75th year; and one which, as had been predicted by Dr. Halley, appeared in 1758, which was supposed to be the same.

The *second* of them appeared in

1532, and 1661, and it was expected that it would again make its appearance in 1789, but in this the astronomers of the present day have been disappointed.

The *third* was that which appeared in 1680, and its period being estimated at 575 years, cannot, upon that supposition, return until the year 2255. This last comet at its *greatest* distance is eleven thousand two hundred millions of miles from the sun, and its *least* distance from the sun's centre was but four hundred and ninety thousand miles; in this part of its orbit it travelled at the rate of 880,000 miles in an hour.

James. Do all bodies move faster or slower in proportion as they are nearer to, or more distant from their centre of motion?

Tutor. They do; for if you look back upon the last six or seven lectures, you will see that the Herschel, which is the most remote planet in the solar system, travels at the rate of 16,000 miles an hour; Saturn, the next nearer in the order, 21,000 miles; Jupiter 28,000 miles; Mars 53,000 miles; the earth 65,000 miles; Venus 75,000 miles; and Mercury at the rate of 105,000 miles in an hour. But here we come to a comet, whose progressive motion, in that part of its orbit which is nearest to the sun, is more than equal to eight times the velocity of Mercury.

Charles. Were not comets formerly dreaded as awful prodigies, intended to alarm the world?

Tutor. Comets are frequently accompanied with a luminous train

called the tail, which is supposed to be nothing more than vapour rising from the body in a line opposite to the sun, but which, to uninformed people, has been a source of terror and dismay.

James. Do comets shine by their own light?

Tutor. It was, till within these few years, supposed that comets borrowed all their light from the sun, but the appearance of two very brilliant comets, of late, seems to have overturned that theory. One of these was visible, for several weeks, in 1807, and the other from September to the end of the year 1811. Of the former, Dr. Herschel has given an elaborate account in the 98th volume of the Philosophical Transactions. Previously to the appearance of these, it was generally

supposed, that the light of comets, like that of the moon and planets, was reflected light only. A new theory is now adopted by Dr. Herschel, and other eminent astronomers, who have had capital opportunities, in both the instances referred to, for accurate observations. Dr. Herschel says, with respect to the comet in 1807, "we are authorized to conclude, that the body of the comet, on its surface, is self-luminous, from whatever cause this quality may be derived. The vivacity of the light of the comet, also, had a much greater resemblance to the radiance of the stars, than to the mild reflection of the sun's beams from the moon."

The same inference has been drawn from the observations made on the comet of last year, which distinctly exhibited, to very powerful

telescopes, the several parts of which the comet is composed.

Charles. What are those parts?

Tutor. They are the *nucleus*, the *head*, the *coma*, and the *tail*.

The *nucleus* is a very small, brilliant, and diamond-like substance in the centre, so small as to be incapable of being measured.

The *head* includes all the very bright surrounding light: inferior telescopes, that will not render the nucleus visible, are often able to exhibit the head thus described. The head of the comet of 1807 was ascertained to be 538 miles in diameter: that of 1811 to be about the size of the moon.

The *coma* is the hairy or nebulous appearance surrounding the head.

The *tail*, which, in some comets, extends through an immense space, it is thought may be most satisfac-

torily accounted for, by supposing it to consist of radiant matter, such as the matter of the Aurora Borealis, than when we unnecessarily ascribe the light to a reflection of the sun's illuminations thrown upon vapours, supposed to arise from the body of the comet. The tail of the comet, in 1807, was ascertained to be more than nine millions of miles in length; and that in 1811 was full 33 millions in length.

James. Was this comet at a great distance from the earth?

Tutor. On the 15th of September, its distance from the sun was more than 95 millions of miles; and its distance from the earth, at the same time, was upwards of 142 millions of miles.

CONVERSATION XXV.

Of the Sun.

TUTOR. Having given you a particular description of the planets which revolve about the sun, and also of the satellites which travel round the primary planets as central bodies, while they are carried at the same time with these bodies round the sun, we shall conclude our account of the solar system by taking some notice of the sun himself,

> Informer of the planetary train,
> Without whose quick'ning glance their cumbrous orbs

Were brute unlovely mass, inert and dead,
And not, as now, the green abodes of life.

THOMSON'S AUTUMN, l. 1086.

James. You told us a few days ago, that the sun has a rotation on its axis, how is that known?

Tutor. By the spots on his surface it is known that he completes a revolution from west to east on his axis in about 25 days, two days less than his *apparent* revolution, in consequence of the earth's motion in her orbit, in the same direction.

Charles. Is the figure of the sun globular?

Tutor. No; the motion about its axis renders it spheroidical, having its diameter at the equator longer than that which passes through the poles.

The sun's diameter is equal to 100 diameters of the earth, and therefore

his bulk must be a million of times greater than that of the earth, but the density of the matter of which it is composed is four times less than the density of our globe.

We have already seen that, by the attraction of the sun, the planets are retained in their orbits, and that to him they are indebted for light, heat, and motion: —

Fairest of Beings! first created light:
Prime cause of beauty! for from thee alone
The sparkling gem, the vegetable race,
The nobler worlds that live and breathe their
    charms,
The lovely hues peculiar to each tribe,
From thy unfailing source of splendour draw!
In thy pure shine, with transport I survey
This firmament, and these her rolling worlds,
Their magnitudes and motions.

Mallet's Excursion.

CONVERSATION XXVI.

Of the Fixed Stars.

TUTOR. We will now put an end to our astronomical Conversations, by referring again to the fixed stars, which, like our sun, shine by their own light.

Charles. Is it then certain that the fixed stars are of themselves luminous bodies; and that the planets borrow their light from the sun?

Tutor. By the help of telescopes it is known that Mercury, Venus, and Mars, shine by a borrowed light, for, like the moon, they are observed

to have different phases according as they are differently situated with regard to the sun. The immense distances of Jupiter, Saturn, and the Herschel planet, do not allow the difference between the perfect and imperfect illumination of their disks or phases to be perceptible.

Now the distance of the fixed stars from the earth is so great, that reflected light would be much too weak ever to reach the eye of an observer here.

James. Is this distance ascertained with any degree of precision?

Tutor. It is not: but it is known with certainty to be so great, that the whole length of the earth's orbit, *viz*. 190 millions of miles, is but a point in comparison of it; and hence it is inferred, that the distance of the

nearest fixed star cannot be less than a hundred thousand times the length of the earth's orbit * ; that is, a hundred thousand times 190 millions of miles, or 19,000,000,000,000 miles: this distance being immensely great, the best method of forming some clear conception of it is to compare it with the velocity of some moving body, by which it may be measured. The swiftest motion with which we are acquainted is that of light, which, as we have seen, is at the rate of 12 millions of miles in a minute; and yet light would be about 3 years in passing from the nearest fixed star to the earth.

A cannon-ball, which may be made to move at the rate of 20 miles in a minute, would be 1800 thousand years

* See Dr. Enfield's Institutes of Natural Philosophy, p. 347, second edition, 1799.

in traversing the distance. Sound, the velocity of which is 13 miles in a minute, would be more than 2 millions 7 hundred thousand years in passing from the star to the earth. So that, if it were possible for the inhabitants of the earth to see the light, to hear the sound, and to receive the ball of a cannon discharged at the nearest fixed star, they would not perceive the light of its explosion for 3 years after it had been fired, nor receive the ball till 1800 thousand years had elapsed, nor hear the report for 2 millions and 7 hundred thousand years after the explosion.

Charles. Are the fixed stars at different distances from the earth?

Tutor. Their magnitudes, as you know, appear to be different from one another, which difference may

arise either from a diversity in their real magnitudes, or in their distances, or from both these causes acting conjointly. It is the opinion of Dr. Herschel, that the different apparent magnitudes of the stars arise from the different distances at which they are situated, and therefore he concludes, that stars of the seventh magnitude are at seven times the distance from us that those of the first magnitude are.

By the assistance of his telescopes he is able to discover stars at 497 times the distance of *Sirius* the Dog-star; from which he infers, that with more powerful instruments he should be able to discover stars at still greater distances.

James. I recollect that you told us once, that it had been supposed by some astronomers, that there might

be fixed stars at so great a distance from us, that the rays of their light had not yet reached the earth, though they had been travelling at the rate of 12 millions of miles in a minute, from the first creation to the present time.

Tutor. I did; it was one of the sublime speculations of the celebrated Huygens. Dr. Halley has also advanced what, he says, seems to be a metaphysical paradox, *viz.* that the number of fixed stars must be more than finite, and some of them at a greater than a finite distance from others: and Mr. Addison has observed, that this thought is far from being extravagant, when we consider, that the universe is the work of infinite power, promoted by infinite goodness, and having an in-

finite space to exert itself in: so that our imagination can set no bounds to it.

How distant some of the nocturnal suns!
So distant, says the sage, 'twere not absurd
To doubt if beams, set out at Nature's birth,
Are yet arriv'd at this so foreign world;
Though nothing half so rapid as their flight.

YOUNG.

Charles. What can be the use of these fixed stars?—not to enlighten the earth, for a single additional moon would give us much more light than them all, especially if it were so contrived as to afford us its assistance at those intervals when our present moon is below the horizon.

Tutor. You are right; they could not have been created for our use, since thousands, and even millions, are never seen but by the assistance of glasses, to which but few of our race

have access. Your minds indeed are too enlightened to imagine, like children unaccustomed to reflection, that all things were created for the enjoyment of man. The earth on which we live is but one of seven primary planets circulating perpetually round the sun as a centre, and with these are connected eighteen secondary planets or moons, all of which are probably teeming with living beings, capable, though in different ways, o. enjoying the bounties of the great First Cause.

The fixed stars then are probably suns, which, like our sun, serve to enlighten, warm, and sustain other systems of planets and their dependent satellites.

James. Would our sun appear as a fixed star at any great distance?

Tutor. It certainly would: and Dr. Herschel thinks there is no doubt, but that it is one of the heavenly bodies belonging to that tract of the heavens known by the name of the *Milky Way.*

Charles. I know the milky way in the heavens, but I little thought that I had any concern with it otherwise than as an observer.

Tutor. The milky way consists of fixed stars, too small to be discerned with the naked eye; and if our sun be one of them, the earth and other planets are closely connected with this part of the heavens.

But, Gentlemen, it is time that we take our leave of this subject for the present. For your attention to those instructions which, on this and other topics, I have been able to commu-

nicate, accept my best thanks. For your future welfare and happiness, my heart is deeply interested. You will not, I flatter myself, very soon forget that connection which has subsisted between us for a long course of years. From my mind the remembrance of your kindness can never be obliterated. Permit me, then, as a testimony of my gratitude and sincere affection, to recommend to your future attention the works of nature and creation, by a careful investigation of which you will necessarily be led to the contemplation and love of the God of Nature.

Your knowledge, young as you yet are, of the fundamental principles of Geometry and Algebra, is such as to render scientific pursuits easy and pleasant. And your understandings

are not more capable of entering into the sublime speculations of science, than your hearts are adapted to receive and cherish those impressions of gratitude, which are the natural consequences of enlarged and comprehensive views of the being and perfections of the Deity. In all your studies and pursuits, then, never forget, that

——————— you cannot go
Where Universal Love not smiles around,
Sustaining all yon orbs, and all their suns;
From seeming evil still educing good,
And better thence again, and better still,
In infinite progression.

Thomson.

END OF THE SECOND VOLUME.

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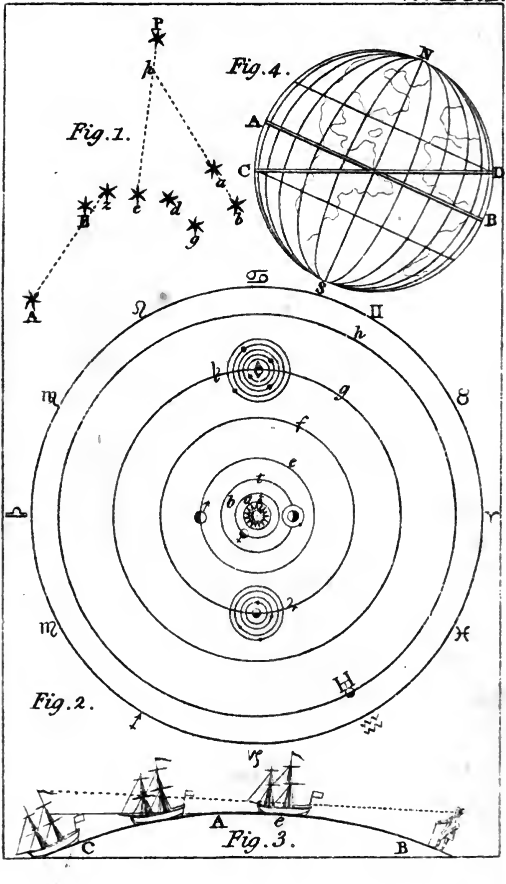
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Fig. 4.
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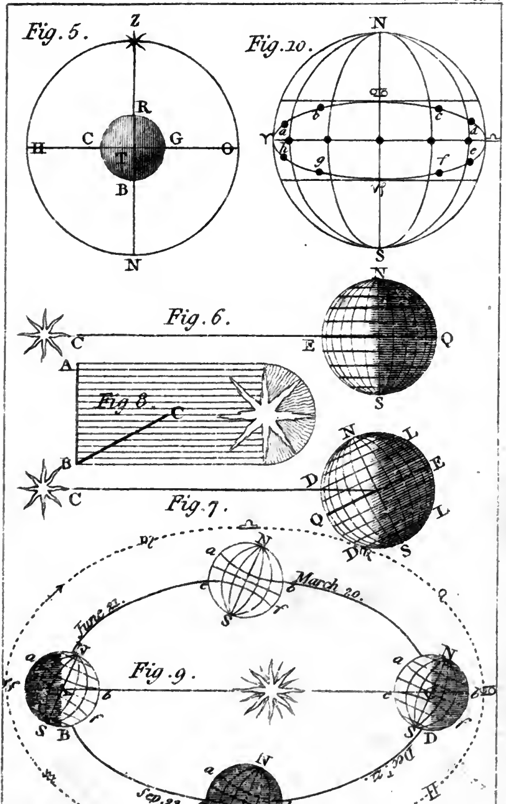
Fig. 5.
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Fig. 9.
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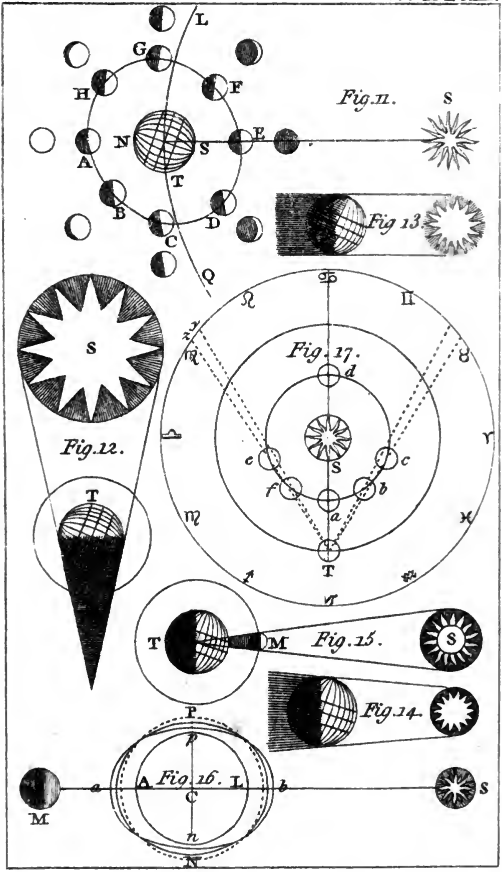
Fig. 11.
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Fig 13.
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Fig.18.

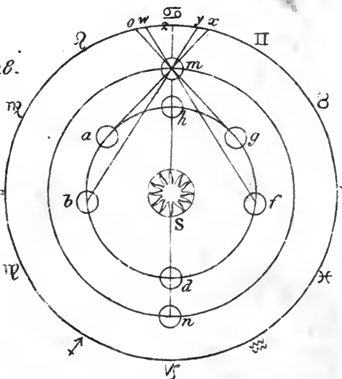

Fig. 20.

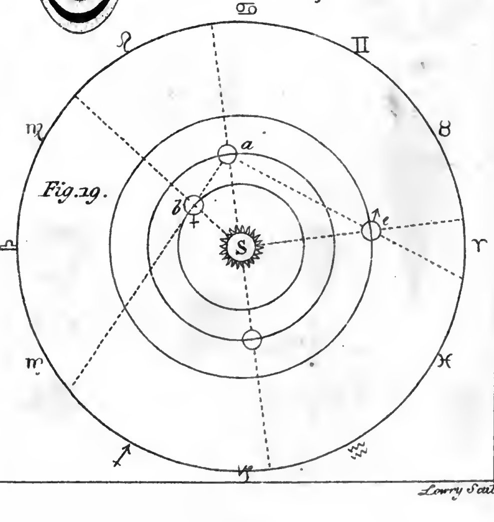

Fig.19.

Lowry Sculp.